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Academy Editors

Proceedings of the

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ARKANSAS ACADEMY OF SCIENCE

VOLUME XXXV
1981

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PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Bookover, 1917
Dwight M. Moore, 1932-33, 64
Flora Haas, 1934
H. H. Hyman, 1935
L. B. Ham, 1936
W. C. Munn, 1937
M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. Wills, 1941-42
L. B. Roberts, 1943-44
Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
G. V. Robinette, 1949
R. H. Totter, 1950
R. H. Austin, 1951
E. A. Spessard, 1952
Delbert Swartz, 1953
Z. V. Harvalik, 1954
M. Ruth Armstrong, 1955
W. W. Nedrow, 1956
Jack W. Sears, 1957
J. R. Mundie, 1958
C. E. Hoffman, 1959
N. D. Buffaloe, 1960
H. L. Bogan, 1961
Trumann McEver, 1962
Robert Shideler, 1963
L. F. Bailey, 1965
James H. Fribourgh, 1966
Howard Moore, 1967
John J. Chapman, 1968
Arthur Fry, 1969
M. L. Lawson, 1970
R. T. Kirkwood, 1971
George E. Templeton, 1972
E. B. Whitlake, 1973
Clark McCarty, 1974
Edward Dale, 1975
Joe Guenter, 1976
Jewel Moore, 1977
Joe Nix, 1978
P. Max Johnston, 1979
E. Leon Richards, 1980

INSTITUTIONAL MEMBERS

The Arkansas Academy of Science recognizes the support of the following institutions through their Institutional Membership in the Academy.

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UNIVERSITY OF ARKANSAS AT LITTLE ROCK
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF CENTRAL ARKANSAS, Conway

EDITORIAL STAFF

Cover: Print of striped skunk by Lou Ann Young

ARKANSAS ACADEMY OF SCIENCE

Volume XXXV **1981**

Proceedings

Henry W. Robison
President

John K. Beadles	David M. Chittenden	William L. Evans	Robert T. Kirkwood
President-Elect	Secretary	Treasurer	Historian

Secretary's Report

MINUTES OF THE SIXTY-FIFTH ANNUAL MEETING—17-18 April 1981

FIRST BUSINESS MEETING

Dr. Henry W. Robison, President, opened the meeting by introducing Dr. Robert Watson, Chairman of the Biology Department at the University of Arkansas at Little Rock, who welcomed the members.

President Robison recognized Dr. David Chittenden who presented the minutes of the 64th annual meeting as printed in the Proceedings. Dr. William Evans was then recognized for the Treasurer's Report. Evans stated that financial statements were available. He then discussed the financial statement and gave a report on income and disbursements. The financial statement and summary of income and disbursements are shown below.

Financial Statement

March 31, 1981

Cash Balance, Checking Acct., McIlroy Bank, March 15, 1980	$2,577.29
Heritage S & L Certificates (2½ yr, 10.65%)	1,000.00
Heritage S & L Passbook Acct. (5.25%)	1,040.85
Total Funds, March 15, 1980	$4,618.14

INCOME March 16, 1980 through March 31, 1981

1. Individual Memberships		
a. Sustaining Dues	$ 576.00	
b. Regular Dues	1,448.00	
c. Associate Dues (Through 12/31/80)	92.00	
Total from Individual Membership Dues		$2,116.00
2. Institutional Dues		700.00
3. Subscriptions to the PROCEEDINGS		948.00
4. Page Charges		952.00
5. BIOTA Receipts		2.70
6. Interest		
a. Checking Account Interest	46.56	
b. Certificate of Deposit Interest	128.40	
c. Passbook Account Interest	71.49	
Total Interest		246.45
Total Income		$4,965.15

EXPENSES March 16, 1980 through March 31, 1981

1. Operating Expenses		
a. McRoy-McNair, Receipt Book (523)	10.79	
b. UofA, Fay, Office Supplies (524)	4.30	
c. Postmaster, Postage (525)	9.10	
d. Postmaster, Box Rent (528)	5.00	
e. Postmaster, Stamps (531)	6.80	
f. McRoy-McNair, Letterheads (532)	34.30	
g. McIlroy Bank, Checks (CA Debit)	11.80	
h. UofA, Fay, Office Supplies (533)	3.94	
i. Postmaster, Box Rent (534)	7.50	
j. Postmaster, Box Rent (540)	7.50	
k. Postmaster, Stamps (541)	7.50	
Total Operating Expenses		$ 108.53
2. Awards		
a. D. Wickliff, Science Talent (520)	$ 35.00	
b. S. Newlin, Science Talent (521)	30.00	
c. Ark. Science Fair Assn. Support (530)	100.00	
d. Ark. Jr. Acad. Sci, Support (532a)	200.00	
e. R. Robinson, Science Proj. (544)	40.00	
f. J. Amerine, Science Proj. (546)	20.00	
g. S. Taylor, Science Proj. (547)	20.00	
h. M. Clyde, Science Proj. (548)	20.00	
Total Awards		$ 465.00
3. PROCEEDINGS, Publishing and Distribution		
a. G. Heidt, Travel (522)	121.68	
b. Phillips Litho, Printing (526)	3,389.94	
c. G. Heidt, Travel (535)	72.00	
d. Editorial Asst. RH, Salary (536)	148.98	
e. IRS, WH Tax (538)	61.32	
f. IRS, WH Tax (539)	6.60	
g. Dept. Fin. & Admin., WH Tax (542)	5.00	
h. Editorial Asst, RH, Salary (545)	184.15	
Total for the PROCEEDINGS		3,989.67
4. NEWSLETTER, Printing and Distribution		
a. V. R. McDaniel, Reimbursement (543)	100.00	
Total for NEWSLETTER		100.00
5. Other		
a. McIlroy Bank, Check Returned (CA Debit)	8.00	
b. Natl. Assn. Acad. Sci, Dues (527)	25.00	
c. UofA, Fay, BIOTA (529)	36.00	
d. E. Hanebrink, Reimb. Page Chg. (537)	102.00	
Total for Other Expenses		171.00
		$4,834.20

Summary

Beginning Balance, Checking & Reserve	$ 4,618.14
Total Income	+4,965.15
Total Expenses	-4,834.20
Funds on Hand, March 31, 1981	$ 4,749.09

Distribution of Funds

Balance, Checking Account, McIlroy Bank, March 31, 1981	$2,466.35
Heritage Savings & Loan Certificates	1,128.40
Heritage Savings & Loan Passbook Account	1,112.34
Undeposited Checks on Hand, March 31, 1981	42.00
Total Funds on Hand, March 31, 1981	$4,749.09

Outstanding Debts, March 31, 1981

1. Phillips Litho., Printing the PROCEEDINGS, v. 34	$4,954.27
2. Editor, Travel	80.00
Total, Outstanding Debts	$5,034.27

Respectfully submitted,

William L. Evans
Treasurer

April 17, 1981
Little Rock, AR.

Dr. Leo Paulissen, reporting on the Westinghouse Talent Search, announced that there had been no winner this year, but that one entry had been awarded an honorable mention. Paulissen also announced that the Biota Survey is continuing. Check sheets from past years were available at the meeting; orders for new check lists will be available at the Second Business Meeting.

President Robison announced that section chairpersons will act as or appoint judges for Collegiate Academy papers.

The following people were appointed to committees by President Robison.

Auditing: Ken Beadles, Dan England, Earl Hanebrink

Resolutions: George Harp, Ed Bacon
Meeting: Peggy Dorris

Dr. Robert Kirkwood was recognized and moved the acceptance of the following resolution:

> Whereas the primary function of a scientist is the development and testing of theories,
>
> And the information on which these theories are based depends upon careful observation and experimentation,
>
> And the observations and experiments of all scientists are susceptible to repetition by other competent scientists who work in the same field,
>
> And the reports of observations and experimentation by scientists are subject to peer review and approval,
>
> And such reports are published in journals approved and accepted by a majority of scientists in the field of science reported in each journal,
>
> And whereas the ideas and beliefs of adherents of so-called "scientific creationism" are not the result of work that can be duplicated, and reports of these ideas and beliefs have not been subject to review and approval by scientists in the fields pertinent to the development of theories of plant and animal origins, and none of these reports has appeared in a journal accepted as authoritative by a majority of scientists in the pertinent fields:
>
> Now, therefore, be it resolved by the members of the Arkansas Academy of Science that we respectfully request that the members of the General Assembly of the State of Arkansas and the governor of the state rescind their action in requiring that equal time be given to the teaching of so called "scientific creationism" and the theory of evolution by natural selection in science classes in the public schools of Arkansas.

The motion was seconded. Discussion of and voting on the resolution will take place at the Second Business Meeting.

President Robison recognized Neal Buffaloe, Chairman of the Nominating Committee, who gave the following report on candidates for offices being vacated.

The Nominating Committee consists of John Bridgman and V. Rick McDaniel and we are pleased to present the nominees for election to the following offices for your consideration.

They are: For President-Elect — Robbin Anderson — UAF
For Vice-President — Paul Sharrah — UAF
For Editor-Elect — V. Rick McDaniel — ASU

Voting will take place at the Second Business Meeting.

SECOND BUSINESS MEETING

President Robison recognized David Chittenden, Secretary, who made the following motion.

> I move that the minutes of the 64th Annual Meeting, published in the 34th Proceedings of the Arkansas Academy of Science be approved as written.

The motion was seconded and passed.

William Evans, Treasurer, made the following motion.

> I move the acceptance and approval of the Treasurer's financial statement and report for the period 16 March 1980 through 31 March 1981, as submitted to the membership and presented at the First Business Meeting.

The motion was seconded.

Ken Beadles, Chairman of the Audit Committee, made the following report.

> Dan England, Earl Hanebrink and myself audited the books. We found the financial record in perfect order and completely balanced. Dr. William L. Evans should be commended for his continuing and diligent work to the Arkansas Academy of Science. His cooperation and enthusiasm is an example for all of us to follow.

The motion of Dr. Evans was passed.

President Robison recognized Gary Heidt, Editor, who gave the following report.

> There were 59 papers (35 feature articles and 24 notes) submitted for Vol. 34 of the Proceedings of the Arkansas Academy of Science. Of these, 24 feature articles and 21 notes were published. There was a total of 134 printed pages which represents the largest volume in the history of the Academy.
>
> The total cost of the Proceedings was $4954.27, of which the Academy should receive $1905 in page charges. The $15 page charge initiated with Vol. 34 was well accepted by the membership. It should be noted that, if the Academy was supported by the scientists in this state, as it should be, page charges would not be needed.
>
> Once again, I would like to thank the Editorial Assistant, Associate Editors, and many reviewers for a job well done.

Dr. Heidt then made the following motion.

> I move that the Academy appropriate $450 for editorial assistance in the preparation of Vol. 35 of the Proceedings.

The motion was seconded and passed.

Robert Kirkwood, Historian, reported that a list of the Academy's meetings and officers will appear in the 35th Proceedings.

V. Rick McDaniel, Editor of the Newsletter, made the following motion.

> I move that the Academy allot $100 for publication of the annual newsletter during the 1981-1982 academy year. This would be the same amount spent during the last year.

The motion was seconded and passed.

Art Johnson, sponsor of the Collegiate Academy, made the following motion.

> I move that the Arkansas Academy appropriate up to $200 to cover the expenses of the Collegiate Academy in the coming year.

The motion was seconded and passed.

Dr. Johnson also moved.

> That the President appoint a committee to study the relationship between the Senior Academy and the Collegiate Academy.

The motion was seconded and passed.

Alex Nisbet, Chairman of the Chemistry Section announced that winners in the judging of papers in the Collegiate Academy were:

Lou Ann Young — UALR
Mike Kowalski — College of Pharmacy, UAMSC

It was also announced that the officers of the Collegiate Academy for 1981-1982 are:

President: Reid D. Hardy — UAM
President-Elect: Brooks Gentry — Hendrix
Treasurer: Dan Monk — UAM
Sponsors: Joe M. Guenter — UAM
Tom E. Goodwin — Hendrix

Tom Palko reported that the J.S.H.S. meeting was outstanding with significant humanities participation. It was pointed out that some J.S.H.S. participants expressed some concern over the failings of the Junior Academy. Gary Tucker made the following motion.

I move that the incoming President of the Senior Academy appoint a committee of three persons to serve as liaison between the Academy and the Junior Academy of Science. This committee hopefully would result in the promotion of a stronger and more effective Junior Academy of Science.

The motion was seconded and passed.

Carl Rutledge, Director of the State Science Fair, reporting on the Science Fair held at UCA, announced that two winners will be sent to the International Fair. They are:

Nathan Knight — Batesville
Landon Lercher — Springdale

Dr. Rutledge pointed out that the input of the Academy was needed in the choice of a new director. He moved

That the President appoint a three member committee to recommend to the Science Fair Association a person for the position of Director of the State Science Fair.

The motion was seconded and passed.

Dr. Rutledge then made the following motion.

I move that $200 be appropriated to cover the expenses of the Science Fair for the coming year.

The motion was passed but the second and motion were withdrawn after Dr. Evans explained the cash flow situation.

Dr. Rutledge then made the following motion.

That $100 be appropriated after July 1 with the approval of the Executive Committee.

The motion was seconded and passed.

President Robison announced that invitations had been issued to have the 1982 meeting at Henderson State University in Arkadelphia and to have the 1983 meeting at the University of Central Arkansas in Conway.

Dr. George Harp, Chairman of the Resolutions Committee, moved the adoption of the following resolution.

Be it resolved:

By the members of the Academy in session on 18 April at the University of Arkansas at Little Rock that the Academy wishes to express its sincere thanks and appreciation to Dr. Robert Watson, Chairman of the Department of Biological Sciences at the University of Arkansas at Little Rock, and to the faculty and staff of the University of Arkansas at Little Rock for the use of their facilities and their warm hospitality.

Furthermore, the Academy extends its congratulations to the local Arrangements Committee, Drs. Dale V. Ferguson and Gary A. Heidt, Co-Chairmen, and to the Chairmen of the Academy sections: Alex Nisbet, Robert Watson, Walter L. Manger, Grady Smith, Neal Buffaloe, Don Culwell, Maurice Kleve, John K. Beadles, Almen Barrons, and Paul Morgan.

The Academy also wishes to express its thanks to Henry W. Robison, President of the Academy, David Chittenden, Secretary, William L. Evans, Treasurer, Gary Heidt, Editor, Robert Kirkwood, Historian, and V. Rick McDaniel, Editor of the Newsletter, for the excellent manner in which they discharged their duties during the past year.

The Academy also expresses its congratulations to the outstanding work of the organizations sponsored by the Academy and its appreciation to the sponsors and directors of these groups: Marie Arthur, Director, Junior Academy of Science; Tom Palko, Director, Junior Science and Humanities Symposium; Art Johnson, sponsor, Collegiate Academy of Science; Carl Rutledge, Director, State Science Fair; Leo Paulissen, Science Talent Search; and Wayne Everett, Coordinator and Liaison Officer for all sponsored activities.

The Academy also expresses its thanks to the following exhibitors: Actinore, Inc.; American Scientific Products; Micro-Tech Instruments, Inc.; Olympus Corporation of America; Rose Publishing Co.; and Southern Biological Supply Co.

The motion was seconded and passed.

The acceptance of the following resolution was moved by Dr. Harp.

Be it resolved:

That the Academy take note of the passing last January of Dr. G. T. Johnson, a member of the Academy for many years. He was a native of Arkansas and a graduate of the University of Arkansas at Fayetteville. He was on the faculty of the Department of Botany and Bacteriology at the University of Arkansas at Fayetteville for almost 30 years. He became internationally known as a mycologist with a special interest in lichens and zinc metabolism in fungi. The Academy extends its condolences to his family, the Department of Botany and Bacteriology, and to the University over this loss.

The motion was seconded and passed.

Neal Buffaloe, Chairman of the Nominating Committee, again presented the slate of nominees for offices. It was moved

That the slate be closed and the officers for 1981-1982 be accepted by acclamation.

The motion was seconded and passed.

President Robison presented the wish of a group of geographers to become associated with the Academy. It was moved

That an invitation be extended to geographers to individually join the Academy. A Geography Section will be established when support and strength is shown.

The motion was seconded and passed.

Secretary's Report

Discussion was opened on the resolution presented by Robert Kirkwood in the First Business Meeting after the motion was seconded. The motion was passed unanimously. The Secretary was directed to distribute this resolution as an open letter to the Governor, the Legislature and the newspapers.

The following report was submitted concerning the activities of the Junior Academy of Science.

The Arkansas Junior Academy of Science meeting was hosted 10 April 1981, by the University of Central Arkansas in Conway, Arkansas, in conjunction with the Arkansas State Science Fair.

Sixty-five research papers were presented by high school students from seventeen schools throughout the state.

Joey Glaub, Nettleton High School, Jonesboro, was chosen by the judges to represent Arkansas at the American Junior Academy of Science which meets in January, 1982 with the American Association of the Advancement of Science convention. Joey's paper is entitled, *The Effects of Hydrocarbon Acid Rain on Seedling Growth of Soybeans, Rice and Turnips.* Rosalyn Edmond, El Dorado High School, was chosen as alternate. Her paper is entitled *Distortions In Proportions.*

Several new schools participated this year and several others have expressed an interest for next year.

The following were elected officers for 1981-82:
President — Lisa Pruitt, Jasper High School
V. President — Valarie Knappe, Wynne High School
Secretary, Treasurer — Raney Fiser, Sheridan High School
Parliamentarian — Billy Deramus

All Arkansas teachers are encouraged to develop and maintain an interest and skills in research among their students.

Anyone wishing more information about the Junior Academy can contact any of the following people: Dr. Wayne Everett, Ouachita Baptist University, Arkadelphia; Mr. Tom Jenkins, Fayetteville High School; Dr. B. C. Dodson, Southern Ark. University, Magnolia; Dr. W. Byrd, Ark. State University, Jonesboro; Mrs. Marie K. Arthur, Magnet Cove High School, Route 5, Box 924, Malvern; Ms. Roberta Bustin, Arkansas College, Batesville; Mrs. JoAnne Rife, Pulaski Co. Schools, Little Rock; Mr. Dennis Glasglow, Little Rock School District.

Dr. Robison turned the gavel over to Dr. Beadles. President Beadles appointed the following committees.

Nominating Committee: Ed Bacon, Gary Tucker, Alan Posey, Alex Nisbet, Chairman.

Collegiate Academy Committee: Nelson Voldeng, Tom Goodwin, Harvey Barton, John Bridgmen, Chairman

Junior Academy Committee: William Byrd, Art Johnson, Tom Palko, Chairman

Science Fair Director Committee: Robert Wright, Bruce Haggard, Joe Guenter

President Beadles adjourned the Second Business Meeting.

Respectfully submitted

David M. Chittenden
Secretary

EDITORIAL COMMENTS

As my term as Editor of the *Proceedings of the Arkansas Academy of Science* has rapidly drawn to an end, I have looked back at the past five years with mixed emotions. On one hand, the position brings with it a great many headaches, including deadlines, poor writing style by some authors, and irate authors feeling that they have been grievously wronged. On the other hand, one makes many new acquaintances and friends, gains an insight into the scientific community not seen by most people and feels that self-satisfaction and pride of seeing a job well done.

Many people deserve a large measure of my thanks for helping produce the last five volumes of the *Proceedings*. Probably the most important person associated with the production of any journal is the Editorial Assistant. My Editorial Assistant, Ms. Robin G. Heidt used her biology and English background plus a sharp eye for detail to edit, correct and check for uniformity in the diverse array of manuscripts submitted. Without her knowledge and ability my job would have been tremendously hampered. The various Associate Editors have also made my job much easier. Of the several Associate Editors who have worked on the *Proceedings* over the past five years, I would like to pay particular thanks to Drs. John K. Beadles (Aquatic Biology), Walter Manger (Geology), Alex Nisbet (Chemistry), Neal Buffaloe (Science Education) and Dale Ferguson (Biology). These men not only played an important role in the collection and evaluation of manuscripts but they also were instrumental in setting up programs for the annual meetings. I also want to thank the many reviewers who have helped review the 200 + manuscripts submitted for publication over the past five years. These persons gave freely of their time and expertise in an effort to produce a proceedings consisting of high quality papers. Finally, I want to express my thanks and appreciation to Mr. Phil Phillips and the staff of Phillips Litho, Inc. in Springdale, Arkansas, who have printed the *Proceedings* during my term as Editor. Of that staff, a particular thanks goes to Ms. Kathy Poore who has more or less ram-rodded the entire production. Without her help, patience, expertise and general good humor the last five volumes would probably have never been completed.

A summary of papers submitted and published in the last five volumes of the *Proceedings of the Arkansas Academy of Science* appears in Table 1. I would like to emphasize two things from the table. First, the format of the *Proceedings* was changed, with Volume 31, to include a General Notes section in addition to the Feature Articles. This was done to allow shorter communications to be published in note form, thus saving space in the *Proceedings*. Furthermore, it has allowed the publication of several communications which might otherwise not have been printed. As can be seen, this section has been successful and if the comments that I have received are reliable, the format has been well accepted.

Secondly, and more importantly, note the percentage of manuscripts which have been either withdrawn or rejected for publication. It has been the ultimate goal of this editor and editorial staff to produce a proceedings indicative of the generally high scientific professionalism found in Arkansas. Unfortunately, in order to accomplish this goal, not all of the submitted manuscripts are judged to be suitable for publication. However, it must be remembered that the journals of any of the state Academies of Science are the most important and often the only outlet for publishing data concerning the local area. This is particularly true as national and regional journals are shifting emphasis toward research of a national or wider regional interest. In addition, the journal of a state's Academy of Science is often the major outlet for publication of papers prepared by graduate and advanced undergraduate students. As such, these journals represent a major part of a student's educational process and an editor must be cognizant of this while evaluating and processing manuscripts. Thus, it becomes the job of the editor and editorial staff to balance the goals of publishing papers of high scientific merit with that of publishing information of local interest and/or students learning the scientific profession. I hope we have accomplished that job over the past five years. I would like to further emphasize that the *Proceedings of the Arkansas Academy of Science* is a refereed journal and not all papers submitted for publication are automatically accepted. Since it is my view that the journals of the state Academies of Science will, in the future, be the major depositories of local information, I strongly feel that the *Proceedings of the Arkansas Academy of Science* both deserves and should be held in a more favorable position by college and university administrators.

As a direct result of my position as Editor, I would like to offer you, my colleagues, two major criticisms. First, it has been my impression from examining numerous student papers, that a number of our state scientists are remiss in their job of teaching students how to compose and write scientific papers. I feel that it is one of our major responsibilities as educators to be sure that individuals leaving our laboratories are well schooled in all aspects of scientific endeavor, including graphics as well as writing. I admonish some of my colleagues to take note and improve this aspect of education. Remember, your students directly reflect back upon you.

Secondly, it was with a great deal of soul-searching that the editorial board had to institute page charges with Volume 34, 1980. IT IS A DISGRACE THAT THE ARKANSAS ACADEMY OF SCIENCE DOES NOT ENJOY THE SUPPORT FROM ARKANSAS SCIENTISTS THAT IT BOTH DESERVES AND NEEDS. To emphasize this point, I would like to list the memberships of the Academies of Science in this area: Arkansas - 250, Missouri - 933, Tennessee - 700, Mississippi - 936, Louisiana - 800, Texas - 900, and Oklahoma - 800. To me this is appalling! Every scientist in this state should support the Arkansas Academy of Science. If the Academy had the full support of the scientific community, page charges would be nonexistant and more services, such as scholarships or special publications, could be provided to Arkansas scientists. I would urge those of you who are members and do support the AAS to put appropriate pressures on your colleagues who aren't.

Finally, I would like to extend my thanks and appreciation to my colleagues in the Arkansas Academy of Science for allowing me the privilege of serving as their Editor for the past five years. It has not only been a valuable learning experience and opportunity to meet and make new friends, but also has given me a great deal of personal satisfaction and pride. I give my best wishes and crying towel to your next Editor, Dr. V. Rick McDaniel.

Gary A. Heidt, Editor
Arkansas Academy of Science, 1977-82

Table 1. Publication Summary of the Proceedings of the Arkansas Academy of Science, 1977-1981.

Volume/Year	Number of Manuscripts Submitted	Number of Manuscripts Rejected or Withdrawn (%)	Number of Manuscripts Published	
			Feature Articles	General Notes
31 - 1977	54	13 (24.1%)	33	8
32 - 1978	39	8 (20.5%)	22	9
33 - 1979	41	5 (12.9%)	19	17
34 - 1980	59	14 (23.7%)	24	21
35 - 1981	32	6 (18.8%)	15	11
Total	225	46 (20.4%)	113	66

PROGRAM
Arkansas Academy of Science

Sixty-Fifth Annual Meeting

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

Little Rock, Arkansas

Meeting concurrently with sessions of:

The Collegiate Academy of Science

Friday, 17 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

COLLEGIATE BUSINESS MEETING

SENIOR ACADEMY -- First General Business Meeting

WESTINGHOUSE SCIENCE TALENT SEARCH AWARDS

Lunch

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:

Chemistry I
Biology I -- Invertebrate Zoology/Physiology
Biomedical Science I
Science Education
Geology

SENIOR AND COLLEGIATE ACADEMIES -- Bar-B-Q

POST BAR-B-Q SPEAKER -- Dr. Kurt Benirschke, Zoological Society of San Diego, "Research Needs in Endangered Species"

Saturday, 18 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:

Biology II -- Botany
Biology III -- Vertebrate Zoology
Aquatic Environment
Chemistry II
Biomedical Science II

SENIOR ACADEMY -- Second General Business Meeting

SECTION PROGRAMS

[Papers marked with * are presentations by Collegiate Academy members]

CHEMISTRY I

Section Chairperson: Alex Nisbet

*DETERMINATION OF STREPTOMYCIN BY GAS-LIQUID CHROMATOGRAPHY USING A MALTOL DERIVATIVE.
Mark W. Woods and Arthur Hoyt, Jr., Department of Chemistry, University of Central Arkansas, Conway, Ark. 72032.

*PROCAINEAMIDE: COLORIMETRIC DETERMINATION OF THE COOPER (II) COMPLEX.
James E. Whitaker and Arthur M. Hoyt, Jr., Department of Chemistry, University of Central Arkansas, Conway, Ark. 72032.

*THE SYNTHESIS OF A SERIES OF METHYL 2, 5- and 5, 6-DIHALONICOTINATES.
W. Reeves Huie and Frank L. Setliff, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

*SYNTHESIS OF N-CYCLOBUTYLMETHYL ANALOGS OF METHADONE, METHADOL, AND ACETYLMETHADOL.
Danny L. Martin and Mike Kowalsky, Department of Biopharmaceutical Sciences, College of Pharmacy, University of Arkansas for Medical Sciences, and Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72205.

*SYNTHESIS OF ENKEPHALIN-LIKE PEPTIDES WITH NARCOTIC ANTAGONIST ACTIVITY.
Danny P. Reese, Department of Chemistry, University of Central Arkansas, Conway, Ark. 72032; and Lisa D. Fox and A. Nelson Voldeng, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

*PREPARATION OF AKLYLIDENECYCLOALKANE.
Dominic T. C. Yang, Ray Emitt, and Jim Purser, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

*SYNTHESIS OF SOME METHYL ESTER DERIVATIVES OF POLYCYCLIC AROMATIC HYDROCARBONS.
Peter P. Fu, National Center for Toxicological Research, Jefferson, Ark. 72279; and Dominic T. C. Yang and Tim Blair, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

ANTI- AND PRO-COAGULANT FIBROGENASES FROM CROTALID VENOMS.
J. B. Moran and C. R. Geren, Department of Chemistry, University of Arkansas at Fayetteville, Fayetteville, Ark. 72701.

VENOM OF THE COMMON HOUSE SPIDER.
Ellen F. Young and Collis R. Geren, Department of Chemistry, University of Arkansas at Fayetteville, Fayetteville, Ark. 72701.

UTILIZATION OF MICROCOMPUTERS FOR SPECTROPHOTOMETRIC ENZYME ASSAYS AND AMINO ACID ANALYSIS.
Collis R. Geren and Bill Burham, Department of Chemistry, University of Arkansas at Fayetteville, Fayetteville, Ark. 72701.

INVERTEBRATE ZOOLOGY/PHYSIOLOGY

Section Chairperson: Robert Watson

USE OF DERMESTID BEETLES IN SKELETON PREPARATION AT THE UNIVERSITY OF ARKANSAS MUSEUM.
Nancy G. McCartney, University of Arkansas Museum, Fayettevillet, Ark. 72701.

THE LAND PLANARIANS *BIPALIUM KEWENSE* AND *GEOPLANA VAGA* IN ARKANSAS.
James J. Daly, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

A COMPARISON OF SOIL TRAVERSING ARTHROPOD POPULATIONS IN SUNFLOWER AND THREE SURROUNDING COMMUNITIES AS SAMPLED BY PITFALL TRAPS.
Linda A. Lee and Harvey E. Barton, Department of Biological Sciences, Arkansas State University, State University, Ark. 72467.

THE PENTATOMIDAE OF ARKANSAS.
Harvey E. Barton and Linda A. Lee, Department of Biological Science, Arkansas State University, State University, Ark. 72467.

FLYING INSECT POPULATIONS AS SAMPLED BY MALAISE TRAP ON CROWLEY'S RIDGE IN NORTHEAST ARKANSAS.
Lynita M. Cooksey and Harvey E. Barton, Department of Biological Science, Arkansas State University, State University, Ark. 72467.

SIGNIFICANCE OF CHALKY DEPOSITS ON FOREWINGS OF *ONCOMETOPIA ORBONA* (F.) (HOMOPTERA: CICADELLIDAE).
Mark A. Mayse. Department of Entomology, University of Arkansas, Fayetteville, Ark. 72701.

A SEM STUDY OF THE CUTICLE OF THREE CASTES OF THE YELLOW JACKET WASP, *VESPULA SQUAMOSA*.
Richard A. Roller, William R. Bowen and Robert L. Watson, Department of Biology, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

A FLUOROGRAPHIC TECHNIQUE FOR DETECTION AND RECORDING CHLOROPHYLL AND ITS DERIVATIVES ON PAPER OR THIN-LAYER CHROMATOGRAMS.
James L. Wickliff, Department of Botany and Bacteriology, University of Arkansas, Fayetteville, Ark. 72701.

GEOLOGY

Section Chairperson: Norman F. Williams

LOWER MISSISSIPPIAN LITHOSTRATIGRAPHY AND CONODONT BIOSTRATIGRAPHY OF NORTHWESTERN ARKANSAS.
W. M. Goodman, W. D. Hawkins, B. K. Jefferies, W. M. Liebe, D. J. Murdaugh, E. J. Post and C. R. Price. Department of Geology, University of Arkansas, Fayetteville, Ark. 72701.

TRANSPORT AND DEPOSITION HISTORY OF THE WEDINGTON SANDSTONE OF NORTHWESTERN ARKANSAS.
Charles R. Price, Department of Geology, University of Arkansas, Fayetteville, Ark. 72701.

TAXONOMY OF THE AMMONOID *PHANEROCERAS*, MORROWAN-ATOKAN (LOWER PENNSYLVANIAN), SOUTHERN MIDCONTINENT, UNITED STATES.
Gary D. Harris, Department of Geology, University of Arkansas, Fayetteville, Ark. 72701.

THE MORROWAN-ATOKAN (PENNSYLVANIAN) BOUNDARY PROBLEM.
Walter L. Manger, Department of Geology and University Museum, University of Arkansas, Fayetteville, Ark., P. K. Sutherland, School of Geology and Geophysics, University of Oklahoma, Norman, Okla.

THE DISTRIBUTION OF FENITIZED CRUSTAL XENOLITHS IN CARBONATITE INTRUSIONS IN WEST-CENTRAL ARKANSAS.
John L. Sharp, Department of Geology, University of Arkansas, Fayetteville, Ark. 72701.

WARM SPRINGS OF ARKANSAS-EXCLUDING HOT SPRINGS NATIONAL PARK.
Kenneth F. Steele and George H. Wagner, Department of Geology, University of Arkansas at Fayetteville, Fayetteville, Ark. 72701.

STRUCTURAL FRAMEWORK OF THE OUACHITA MOUNTAINS, ARKANSAS.
Boyd R. Haley and Charles G. Stone, U. S. Geological Survey and Arkansas Geological Commission, Little Rock, Ark. 72204.

A CASE HISTORY OF A MAJOR LANDSLIDE ON CROWLEY'S RIDGE, VILLAGE CREEK STATE PARK, ARKANSAS.
John D. McFarland III and Charles G. Stone, Arkansas Geological Commission, Little Rock, Ark. 72204.

SMOKY QUARTZ IN RESIDUAL BAUXITE, SALINE COUNTY, ARKANSAS.
J. Michael Howard, Arkansas Geological Commission, Little Rock, Ark. 72204.

DEEP-WATER DEPOSITION OF ORDOVICIAN STRATA IN THE OUACHITA MOUNTAINS, ARKANSAS AND OKLAHOMA.
Charles G. Stone and Boyd R. Haley, Arkansas Geological Commission and U. S. Geological Survey, Little Rock, Ark. 72204.

BIOMEDICAL SCIENCES I
Section Chairperson: Grady Smith

OXIDATION OF NATIVE AND MODIFIED HEMOGLOBIN (Hb) AND MYOGLOBIN (Mb) BY SODIUM NITRITE IN THE PRESENCE AND ABSENCE OF OXYGEN, INOSITOL HEXAPHOSPHATE (IHP) AND CATALASE.
A. Mansouri, Department of Medicine, VA Medical Center and University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

UNAMBIGUOUS EVALUATION OF COUPLING CAPACITY OF ARSENATE-TREATED MITOCHONDIRA.
C. Bhuvaneswaran, Department of Biochemistry, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

COPPER DEFICIENCY AND ADJUVANT-INDUCED POLYARTHRITIS IN RATS.
V. Kishore, N. Latman, J. Potter, L. Hohnson and J. R. J. Sorenson, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

INFLUENCE OF CADMIUM ($CdCl_2$) ON THE PLASMA ANTITRYPTIC ACTIVITY (TIC) OF MICE.
Parimal Chowdhury and Phillip L. Rayford, Department of Physiology and Biophysics, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

EFFECT OF PARTIAL ILEAL BYPASS ON SERUM LIPOPROTEINS.
Charles A. Nelson and Manford D. Morris, Department of Biochemistry and Pediatrics, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

EFFECTS OF SUPRACHIASMATIC AND HIPPOCAMPAL LESIONS ON THE CIRCADIAN INTAKE OF WATER AND ETHANOL IN MICE.
James N. Pasley and Ersin W. Powell, Departments of Physiology-Biophysics and Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

DISCRIMINATION OF THE PHENCYCLIDINE DRUG STATE IN THE PIGEON: GENERALIZATION TO OTHER DRUGS.
D. E. McMillan, Department of Pharmacology and Interdisciplinary Toxicology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

THE EQUIVALENCE OF MORPHOGENETIC MECHANISMS IN REGENERATING AND DEVELOPING FORELIMBS OF THE MEXICAN SALAMANDER, *AMBYSTOMA MEXICANUM*.
Patrick W. Tank, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

*PURIFICATION AND PARTIAL CHARACTERIZATION OF CALMODULIN FROM THE MYXOMYCETE *PHYSARUM FLAVICOMUM*.
Lou Ann Young and Thomas J. Lynch, Department of Biology, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

IS CYCLIC 3'5' CYTIDINE MONOPHOSPHATE (cCMP) A NORMAL METABOLITE?
Joseph E. Stone, Department of Pharmacology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

SCIENCE EDUCATION
Section Chairperson: Neal Buffaloe

A STUDY OF THE HIGH SCHOOL PHYSICS PROGRAM AND ENROLLMENTS IN THE STATE OF ARKANSAS.
Ralva Bass and Maurice Ayers, Department of Physics, University of Central Arkansas, Conway, Ark. 72032.

100 YEARS OF PHYSICS AT THE UNIVERSITY OF ARKANSAS.
Paul C. Sharrah, Department of Physics, University of Arkansas, Fayetteville, Ark. 72701.

APPLE COMPUTER PROGRAMS FOR PHYSICS AND ASTRONOMY EDUCATION.
Carl T. Rutledge, Department of Physics, Southern Arkansas University, Magnolia, Ark. 71753.

OF SIMPLE SUBSTANCES.
Billie G. Broach, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

POLYMERS AND MACROMOLECULES IN CHEMISTRY (AND BIOLOGY) PROGRAMS.
Robbin C. Anderson, Department of Chemistry, University of Arkansas, Fayetteville, Ark. 72701.

MODELS FOR THE STUDY OF CUBIC CRYSTALLOGRAPHIC POINT GROUPS.
A. F. Gremillion, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

OPERATION HEARTBEAT.
Dennis R. Glasgow, Thomas A. Bruce, John E. Pauly and Lawrence E. Scheving, Office of Science and Environmental Education, Little Rock Public School System; and Office of the Dean and Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

A SIMPLE CELL MODEL ANYONE CAN CONSTRUCT FOR A GENERAL BIOLOGY PRESENTATION.
Donald E. Culwell, Department of Biology, University of Central Arkansas, Conway, Ark. 72032.

SURVIVAL TECHNIQUES FOR FIELD PROGRAMS IN THE 80's.
James E. Edson, Department of Natural Sciences, University of Arkansas at Monticello, Monticello, Ark. 71655.

CROWLEY'S RIDGE BIOLOGICAL STATION—AN EDUCATION CENTER.
Jewel E. Moore, Department of Biology, University of Central Arkansas, Conway, Ark. 72032.

COMPUTER LITERACY IN SCIENCE EDUCATION.
N. Minx Olsen, NSF/CAUSE project, University of Arkansas at Monticello, Monticello, Ark. 71655.

A DISCUSSION OF A PERSONAL OPINION IN RELATIONSHIP TO SCIENCE VS RELIGION.
Joe Green, TRACE Corporation, North Little Rock, Ark. 72116.

BOTANY
Section Chairperson: Don Culwell

LICHENS OF ARKANSAS II. ADDITIONAL STATE RECORDS FROM COMPUTER SEARCH.
Jewel E. Moore, Department of Biology, University of Central Arkansas, Conway, Ark. 72032.

CHECKLIST OF ARKANSAS MOSSES.
Jewel E. Moore, Department of Biology, University of Central Arkansas, Conway, Ark. 72032 and Paul L. Redfearn, Jr., Department of Biology, Southwest Missouri State University, Springfield, Mo. 65801.

CHECKLIST OF ARKANSAS HORNWORTS AND LIVERWORTS.
Jewel E. Moore, Department of Biology, University of Central Arkansas, Conway, Ark. 72032 and Eugene B. Wittlake, Jr., Department of Biology, Arkansas State University, State University, Ark. 72467.

POLLEN STUDIES IN THE NOLANACEAE.
Johnnie L. Gentry, Jr., University of Arkansas Museum, Fayetteville, Ark. 72701.

THE FOREST VEGETATION OF HOT SPRINGS NATIONAL PARK, ARKANSAS.
Edward E. Dale, Jr. and Michael R. Watts, Department of Botany and Bacteriology, University of Arkansas, Fayetteville, Ark. 72701.

ORDINATION OF FOREST TYPES IN THE BLACK SWAMP.
J. Barton Fogleman and P. L. Raines, Department of Biological Sciences, Arkansas State University, State University, Ark. 72467.

CLASSIFICATION AND PROTECTION STATUS OF REMNANT NATURAL PLANT COMMUNITIES IN ARKANSAS.
William F. Pell, Arkansas Natural Heritage Commission, Little Rock, Ark. 72201.

NEW RECORDS AND UPDATES ON THE ARKANSAS FLORA.
Richard H. Davis, Arkansas Heritage Program, Little Rock, Ark. 72201.

VERTEBRATE ZOOLOGY
Section Chairperson: Maurice Kleve

WILDLIFE HABITAT IMPROVEMENT ON THE OUACHITA NATIONAL FOREST: AN UPDATE.
David A. Saugey, Ouachita National Forest, Hot Springs, Ark. 71901.

THE EFFECTS OF MICROHABITAT DISTRIBUTION ON PREY UTILIZATION OF SYMPATRIC POPULATIONS OF *PLETHODON GLUTINOSUS* AND *PLETHODON DORSALIS* IN NORTHWESTERN ARKANSAS.
James M. Britton, Department of Zoology, University of Arkansas, Fayetteville, Ark. 72701.

SUCCESS OF WILD-TRAPPED COMPARED TO CAPTIVITY-RAISED BIRDS IN RESTORING WILD TURKEY POPULATIONS TO NORTHWESTERN ARKANSAS.
Douglas James, L. Glen Fooks and John R. Preston, University of Arkansas, Fayetteville, Ark. 72701 and Southern Baptist College, Walnut Ridge, Ark. 72467 and Oklahoma City Zoo, Oklahoma 73111.

*IMMUNE RESPONSE OF THE COMMON GRACKLE TO FILARIAL INFECTION OF THE BRAIN WITH *CHANDLERELLA QUISCALI.*
Richard L. Hester, Roger G. Rank and Arthur A. Johnson, Department of Biology, Hendrix College, Conway, Ark. Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

A CRITICAL HABITAT DETERMINATION FOR THE RED-COCKADED WOODPECKER IN ARKANSAS.
Fred L. Burnside and Douglas James, Arkansas Highway and Transportation Department, Little Rock, Ark. and University of Arkansas, Fayetteville, Ark. 72701.

*EFFECTS OF ETHANOL ON BRAIN ZINC CONCENTRATION IN THE RAT.
J. Russell, E. Riddell, R. E. Stull, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

A NOTE ON THE INCIDENCE OF *DIROFILARIA IMMITIS* IN THE WILD CANIDAE OF NORTHEAST ARKANSAS.
Anthony W. King and Anna Marie Bohning, Department of Biological Sciences, Arkansas State University, State University, Ark. 72467.

ON TROPHIC ADAPTATIONS OF THE WILD CANID COMMUNITY OF NORTHEAST ARKANSAS.
Anthony W. King, Department of Biological Sciences, Arkansas State University, State University, Ark. 72467.

FOOD RESOURCE PARTITIONING IN A BAT COMMUNITY.
Ken N. Paige, Department of Biology, Arkansas State University, State University, Ark. 72467.

DISTRIBUTION OF THE RIVER OTTER (*LUTRA CANADENSIS*) IN ARKANSAS.
C. Renn Tumlison and Anthony W. King, Department of Biology, Arkansas State University, State University, Ark. 72467.

ANOMALIES OF BOBCAT SKULLS *(FELIS RUFUS)* IN ARKANSAS.
C. Renn Tumlison and V. Rick McDaniel, Department of Biology, Arkansas State University, State University, Ark. 72467.

A PROFILE OF SKUNK RABIES IN ARKANSAS: 1980.
Angy Yeager, Gary A. Heidt and Dale V. Ferguson, Department of Biology, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

NOTES ON THE NESTING BEHAVIOR OF THE CHUCK-WILLS-WIDOW *CAPRIMULGUS CAROLINEUSIS*.
Ed Price and Earl L. Hanebrink, Department of Biological Sciences, Arkansas State University, State University, Ark. 72467.

CHEMISTRY II
Section Chairperson: Alex Nisbet

SIMPLE AMORPHOUS SALTS: SPECTR AND GLASS TRANSITION TEMPERATURES.
Keith Consani and J. Paul Devlin, Department of Chemistry, Oklahoma State University, Stillwater, Oklahoma 74078. Alex Ray, Henry Farrar III and Edmond W. Wilson, Jr., Department of Chemistry, Harding University, Searcy, Ark. 72143.

TUBE-FURNACE STUDIES OF THE VAPORIZATION REACTION OF K_2SO_3.
Wade Martin Simpson and J. Edward Bennett, Department of Chemistry, Arkansas State University, State University, Ark. 72467.

KNUDSEN-MODE HIGH-TEMPERATURE THERMOGRAVIMETRIC ANALYSIS: VOLATILIZATION REACTION OF K_2SO_3.
Wade Martin Simpson and J. Edward Bennett, Department of Chemistry, Arkansas State University, State University, Ark. 72467.

SYNTHESIS PROBLEMS ASSOCIATED WITH CYANOCHLOROCHROMATES.
David Jimerson and Richard Vanderpool, Department of Chemistry, Arkansas State University, State University, Ark. 72467.

SYNTHESIS OF (E)-1-ARYL-2-METHYL-3-ALKYL-2-PROPEN-1-ONES VIA ALLYLIC SULFOXIDE-SULFENATE ESTER REARRANGEMENTS.
T. E. Goodwin, D. G. Ratcliff, C. M. Crowder and N. K. Seitzinger, Department of Chemistry, Hendrix College, Conway, Ark. 72032.

ENZYME: A CBM-BASIC PROGRAM FOR SIMULATION OF ENZYME INHIBITION.
Tim Best, Department of Chemistry, Hendrix College, Conway, Ark. 72032.

THE REACTION OF ESTER ENOLATES WITH HEX-1-ENOPYRAN-3-ULOSES.
T. E. Goodwin, B. D. Curtner, J. F. Loomis, and D. G. Ratcliff, Department of Chemistry, Hendrix College, Conway, Ark. 72032.

THE REACTION OF PHENYLTHIO(ALKYL)CUPRATE REAGENTS WITH A HEX-1-ENOPYRAN-3-ULOSE.
T. E. Goodwin, C. M. Crowder and R. B. White, Department of Chemistry, Hendrix College, Conway, Ark. 72032.

PREPARATION OF AN AROMATIC SYNTHON FOR MAYTANSINOID SYNTHESIS.
T. E. Goodwin and L. A. Covey, Department of Chemistry, Hendrix College, Conway, Ark. 72032.

AN IMPROVED OXIDATION METHOD FOR THE SYNTHESIS OF 2,5- and 5,6-DIHALONICOTINIC ACIDS.
Frank L. Setliff and W. Reeves Huie, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

AQUATIC ENVIRONMENT
Section Chairperson: John K. Beadles

A NOTE ON THE FECUNDITY OF THE LEAST BROOK LAMPREY, *LAMPETRA AEPYPTERA* (ABBOTT), FROM NORTHCENTRAL ARKANSAS.
Chris T. McAllister, Michael C. Wooten and Timothy L. King, North Texas State University, Denton, Tex. 76203. Arkansas State University, State University, Ark. 72467.

A PRELIMINARY REPORT ON THE FISHES OF THE UPPER SALINE RIVER IN POLK AND HOWARD COUNTIES, ARKANSAS.
Stephen A. Sewell, Arkansas State University, State University, Ark. 72467.

SEASONAL ABUNDANCE, MOVEMENT AND DIVERSITY OF FISHES IN AN OZARK STREAM.
Michael R. Dewey, University of Arkansas, Fayetteville, Ark. 72701.

RATION/DENSITY COMPARISONS WITH CAGED CHANNEL CATFISH.
Scott H. Newton and Walter R. Robison, University of Arkansas at Pine Bluff, Pine Bluff, Ark. 71601.

*WINTER FEEDING OF FINGERLING CHANNEL CATFISH IN CAGES.
Darryl B. Burke and Walter R. Robinson, University of Arkansas at Pine Bluff, Pine Bluff, Ark. 71601.

THE AQUACULTURE INDUSTRY OF ARKANSAS IN 1980.
Donald H. Fiegel and Mike Freeze, Arkansas Game and Fish Commission, Little Rock, Ark.

MATURATION, SPAWNING PERIOD AND FECUNDITY OF THE WHITE CRAPPIE., *POMOXIS ANNULARIS* RAFINESQUE, IN BEAVER RESERVOIR, ARKANSAS.
Janet L. Thomas and Raj V. Kilambi, University of Arkansas, Fayetteville, Ark. 72701.

ECONOMICS OF RAINBOW TROUT PRODUCTION IN ARKANSAS.
Walter R. Robison and Scott H. Newton, University of Arkansas at Pine Bluff, Pine Bluff, Ark. 71601.

BIOLOGY OF THE STRIPED BASS, *MORONE SAXATILIS*, FROM BEAVER RESERVOIR, ARKANSAS.
Raj V. Kilambi and Alex Zdinak, University of Arkansas, Fayetteville, Ark. 72701.

DESCRIPTION OF THE NYMPH OF *GOMPHUS OZARKENSIS* WESTFALL (ODONATA: GOMPHIDAE).
George L. Harp, Arkansas State University, State University, Ark. 72467.

*WINTER FEEDING OF FINGERLING CHANNEL CATFISH.
Scott H. Newton and Calvin J. Hoskins, University of Arkansas at Pine Bluff, Pine Bluff, Ark. 71601.

TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN LAKE DARDANELLE, 1971-1980.
John D. Rickett, Department of Biology, University of Arkansas at Little Rock, Little Rock, Ark. 72204.

THE OBSERVED AQUATIC LIFE OF LAKE CUYABENO OF ECUADOR.
Michael F. Carter, Department of Biology, University of Central Arkansas, Conway, Ark. 72032.

BIOMEDICAL SCIENCES II

Section Chairpersons: Almen Barrons and Paul Morgan

*MOLECULAR CLONING OF CRICKET 5S RNA GENES IN *ESCHERICHIA COLI*.

Helen Benes and M. Donald Cave, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

*DEVELOPMENT OF A BILEVEL SCREENING PROCEDURE FOR POTENTIAL ANTI-TUMOR COMPOUNDS.

David G. Ratcliff, Department of Biology, Hendrix College, Conway, Ark. 72032.

*THE EFFECTS OF GRADED EXERCISE ON SLEEP.

Pedro Abad and E. A. Lucas, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

*THE EFFECTS OF PURIFIED *SALMONELLA ENTERITIDIS* ENDOTOXIN ON THE IMMUNE RESPONSE OF BALB/C MICE.

John B. Barnett and John Jutila, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205 and Department of Microbiology, Montana State University, Bozeman, Montana.

IDENTIFICATION OF AN ALPHA-ADRENERGIC BINDING SITE IN A TUMOR CELL LINE DERIVED FROM GOLDEN HAMSTER DUCTUS DEFERENS.

Lawrence E. Cornett and James S. Norris, Departments of Physiology-Biophysics and Medicine, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

NON-MEASLES HEMADSORPTION IN A CELL LINE PERSISTENTLY INFECTED WITH MEASLES VIRUS (BGM/MV).

Jay H. Menna and John D. May, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

CHROMOBIOLOGY AND ITS IMPORTANCE TO EXPERIMENTAL AND CLINICAL CHEMOTHERAPY.

Lawrence E. Scheving, John E. Pauly and Tien-Hu Tsai, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

THE UTERUS AND FUNCTIONAL LIFE-SPAN OF THE CANINE CORPUS LUTEUM-PRELIMINARY REPORT.

Horace N. Marvin, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

EFFECT OF NOCTURNAL ILLUMINATION OF SLEEP-WAKE (SW) PATTERNS OF THE CAT.

Edgar A. Lucas, Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205.

INHIBITION OF ETHIDIUM BROMIDE OF THE SYNTHESIS OF CIRCULAR DNA IN SPERMATOCYTES OF *RHYNCHOSCIARA HOLLAENDERI* LARVAE.

Clifton Orr, Department of Pharmacology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72205 and John Papaconstantinou and Emilla M. Julku, The Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn. 37830.

Arkansas Collegiate Academy of Science

Jane Spradley
President

Reid Hardy
President-Elect

Dr. Arthur Johnson
Sponsor

MINUTES OF THE BUSINESS MEETING, 18 APRIL 1981

The meeting was brought to order at 11:00 A.M. The president-elect for the 1980-81 year, James Briggs, was not present, and would not be available to fulfill the presidency for the 1981-82 year.

A discussion was held by persons attending the meeting as to the function of the Collegiate Academy and what its future would be. Dr. Arthur Johnson announced that he has made a proposal to the Senior Academy that a committee from the AAS be appointed to investigate these matters during the 1981-82 year.

A new president, Reid Hardy from the University of Arkansas at Monticello, was elected. Brooks Gentry of Hendrix College was elected president-elect.

The meeting was adjourned at 11:30 A.M.

Respectfully Submitted,

Jane Spradley
President
Arkansas Collegiate Academy
1980-81

ABSTRACTS OF PAPERS PRESENTED BY COLLEGIATE ACADEMY MEMBERS

Editor's Note: Not included in the following abstracts is that of Darryl B. Burke, whose paper was accepted for publication and is presented elsewhere. Titles of papers presented by Collegiate Academy members are identified in the preceding Section Programs by *.

THE EFFECTS OF GRADED EXERCISE ON SLEEP.

Pedro Abad and E. A. Lucas, Dept. of Anatomy, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

Restorative theories of sleep predict an increase in Slow Wave Sleep (SWS or Delta sleep) following exercise; however, several investigators have failed to find such an effect. We tested the effects of exercise on the sleep of eight healthy males between 22 and 27 years of age who had similar training backgrounds. They underwent all-night polysomnographic recordings for eight consecutive nights on a Grass 78 B polygraph at 15 mm/sec with simultaneous tape recordings. Each 20 seconds of record was scored blind for sleep stages according to the Rechtschaffen and Kales manual and evaluated by t-test statistics. There were three baseline, three exercise and two recovery nights. Each subject pedalled at a constant rate of 60 RPM at 50% of his pre-determined maximum work capacity on a bicycle ergometer in two 45 min periods between 1600 and 1745 hours. The results show that there are no significant differences between sleep measures including delta sleep when the three conditions are statistically compared. Comparisons restricted to the first half of the night also failed to reveal any significant differences; however, there was more stage 3, stage 4 and delta sleep for 6 of the 8 subjects in both half night and whole night comparisons. Although the amount of delta sleep may not be significantly increased, the relative amount of delta wave activity may be elevated following exercise. We are performing spectral analysis of each night's recording on magnetic tape to determine the relative power of low frequency activity.

MOLECULAR CLONING OF CRICKET 5S RNA GENES IN *ESCHERICHIA COLI*.

Helen Benes and M. Donald Cave. Dept. of Anatomy, Univ. of Arkansas for Med. Sci., Little Rock, Ark. 72205.

The structure and expression of the 5S, 5.8S, 18S and 28S RNA genes are of considerable interest since their RNA transcripts are essential components of the ribosome. In the cricket, *Acheta domesticus*, the 18S and 28S rRNA genes are amplified during oogenesis and have been mapped by restriction endonucleases (RE). As a first step in a study of the 5S RNA genes of the cricket, molecular cloning techniques were applied to isolate these genes. Purified genomic DNA from cricket testes was digested with the RE Eco RI to obtain DNA fragments for cloning in the lambda (λ) bacteriophage, Charon 4. Recombinant phage DNA was generated by ligation of cricket DNA fragments to the long arms of Charon 4 DNA, packaged into viable phage particles and amplified by infection of *E. coli* strain CSH18. The resulting library of recombinant DNA molecules representing the cricket genome was screened by nucleic acid hybridization techniques to identify clones containing cricket 5S RNA genes. DNA from 8 such clones was purified, digested with Eco RI and analyzed by agarose gel electrophoresis and the Southern blotting procedure. Those Eco RI fragments shown to hybridize to ^{32}P-labeled 5S RNA (purified from *A. domesticus*) were inserted into the plasmid pBR322. Transformation of *E. coli* strain HB101 with the recombinant plasmids yielded clones which were screened for cricket 5S RNA genes by colony hybridization. Recombinant plasmid DNA containing cricket 5S RNA genes was resolated for subsequent RE mapping of the eukaryotic genes.

SYNTHESIS OF SOME METHYL ESTER DERIVATIVES OF POLYCYCLIC AROMATIC HYDROCARBONS.

Peter P. Fu, National Center for Toxicological Research, Jefferson, AR 72279 and Dominic T. C. Yang and Tim Blair, Dept. of Chemistry, UALR, Little Rock, AR 72204.

Introduction of methyl groups to polycyclic aromatic hydrocarbons sometimes can change profoundly the biological activity of the molecule, either enhance or eliminate its carcinogenic potential. Enzymatic oxidation of the side chain to carboxyl derivative leads to one of the known PAHs matabolite.

Reaction of some polycyclic aromatic hydrocarbons with oxalyl chloride, followed by methanolysis will be discussed.

IMMUNE RESPONSE OF THE COMMON CRACKLE TO FILARIAL INFECTION OF THE BRAIN WITH *CHANDLERELLA QUISCALI*.

Richard L. Hester, Roger G. Rank, and Arthur A. Johnson, Dept. of Biology, Hendrix College, Conway, Ark. 72032, Dept. of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, Ark. 72204.

Adult *Chandlerella quiscali* were collected from the cerebral surface of common grackles (*Quiscalus quiscula*) and homogenized in phosphate buffered saline. Rabbits were injected intramuscularly (IM) with 4.5 mgs of the worm antigen (WA) in Freund's complete adjuvent and boosted IM with 1 mg 14 days later. The resultant antiserum (anti-WA) produced 3 precipitin bands when reacted with WA by immunodiffusion techniques. Sera were collected from infected grackles and of 24 sera tested against WA all were positive for circulating antibody. All grackle sera showed at least one line of partial identity with the anti-WA when both were tested against WA. Five of the grackle sera demonstrated two distinct lines, both showing identity with a single line formed by WA and anti-WA. These data demonstrate that grackles produce antibody against at least one and in some cases two *Chandlerella* antigens. The source of these antigens remains to be determined but it is interesting to note that both adults and microfilariae survive in the presence of specific antibody.

The following paper was a co-winner of the outstanding collegiate award.

SYNTHESIS OF N-CYCLOBUTYLMETHYL ANALOGS OF METHADONE, METHADOL, AND ACETYLMETHADOL.

Danny L. Lattin and Mike Kowalsky, Department of Biopharmaceutical Sciences, College of Pharmacy, University of Arkansas for Medical Sciences and Department of Chemistry, University of Arkansas at Little Rock, Little Rock, Arkansas.

The N-cyclobutylmethyl analogs of (+)-N-normethadone, (−)-α-normethadol, and (−)-α-acetyl-N-normethadol have been synthesized. This synthesis is part of an effort to determine the structural and stereochemical requirements for opiate antagonist activity of the methadone series (methadone, methadol, acetylmethadol) of opiate analgesics. The synthesis of the title compounds and the implications of these compounds to the study of opiate antagonists will be discussed.

This research was supported by the 1980 Undergraduate Research Participation program of the National Science Foundation, Grant No. NSF SPI-7926630.

THE SYNTHESIS OF A SERIES OF METHYL 2,5- AND 5,6-DIHALONICOTINATES.

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The preparation of the methyl esters of various 2,5- and 5,6- dihalonicotinic acids by the diazomethane procedure is discussed. Spectral properties of the esters are also presented, along with a brief description of the synthetic schemes for the preparation of the dihaloacids.

DEVELOPMENT OF A BILEVEL SCREENING PROCEDURE FOR POTENTIAL ANTI-TUMOR COMPOUNDS.

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In connection with ongoing organic synthesis research at Hendrix, a two level screen is presently being developed to investigate the cytotoxic activity of synthetic compounds. An initial *in vitro* study is described in which tubulin polymerization inhibition properties of the subject compound are assayed. A second *in vivo* screen is performed utilizing the Erlich ascites tumor system injected interperitonealy in mice. Suppressed tumor growth, increased survival time of the host, and stathmokinetic properties of the compound in question are investigated.

SYNTHESIS OF ENKEPHALIN-LIKE PEPTIDES WITH NARCOTIC ANTAGONIST ACTIVITY

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Enkephalins are endogenous peptides composed of five amino acids (Met¹-enkephalin = try-gly-gly-phe-met) and have been shown to elicit brief, but remarkable opiate-like activity when tested in laboratory animals. Synthetic modifications of the enkephalins have yielded compounds which produce significant analgesia in mice or rats when administered parenterally or orally. Unfortunately these derivatives appear to possess the addiction liability common with potent analgesics. Discussion will include rational for the synthesis of specific enkephalin derivatives whose conformation more closely conforms to the rigid structure of morphine, will be longer acting than the endogenous enkephalins, will be effective when administered orally, and will possess significant analgesic activity. In an effort to prevent the physical dependence associated with the enkephalins, organic moietics which possess narcotic antagonist activity will be attached to specific sites in these peptides. Synthetic approaches to these peptides will also be presented.

This research was supported by the 1980 Undergraduate Research Participation program of the National Science Foundation, Grant No. NSF SPI-7926630.

EFFECTS OF ETHANOL ON BRAIN ZINC CONCENTRATION IN THE RAT.

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Zinc concentrations were significantly diminished in select areas of the brains from rats fed a liquid diet obtained from Bio-Serv, Inc. which supplied approximately 35% of the caloric requirement as ethanol. Following various time periods of exposure to the diet, animals were sacrificed and brains quickly removed. Pair-fed animals which received an isocaloric diet served as controls. The brains were sectioned into cortex, upper and lower brain stem, hippocampus, and olfactory lobes. Atomic absorption spectroscopy revealed that zinc levels were significantly reduced within the hippocampus ten days following ethanol, within normal limits at 15 days and again reduced 28 days post ethanol. Zinc was likewise diminished in content in the upper brain stem section at 28 days. The concentration of zinc was not significantly altered in any of the other brain sections analyzed at time periods tested, nor were zinc levels diminished in plasma or livers taken from these animals.

This study was supported in part by a grant from the Distilled Spirits Council of the United States, Inc.

PROCAINEAMIDE HYDROCHLORIDE: COLORIMETRIC DETERMINATION OF THE COPPER (II) COMPLEX.

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Procaineamide·HCl was complexed with copper (II), producing a new absorption centered at 380 mm. The complex was found to be 1:1 procaineamide · HCl:Cu^{+2}. Complex formation was maximized at pH 4.0-4.3. Acetate buffers produced the best results, but coordination was maintained even in biphthalate buffer although the reaction was damped by approximately 50%. Complex formation was shown to be linear with respect to the initial procaineamide·HCl concentration at drug concentrations less than 8 mg/ml. Preliminary work indicates possible applications of this reaction in the analysis of commercial preparations of the drug.

DETERMINATION OF STREPTOMYCIN BY GAS-LIQUID CHROMATOGRAPHY USING A MALTOL DERIVATIVE.

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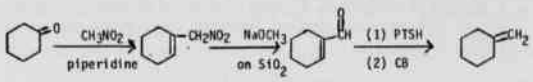
Current analytical methods for streptomycin range from biological assays using inhibition of bacterial growth to colorimetric methods. Current methods lack speed or specificity and some are only semi-quantitative. In this study gas-liquid chromatography of a streptomycin derivative was performed using a 10% SE30 packing on a support of 80/100 mesh Chromosorb W. The streptomycin was reacted with 1 N NaOH at 100°C to give maltol as one of the products. This basic solution was acidified and the maltol was extracted with chloroform. The maltol was derivatized with N-Methyl-N-TMS-Trifluoroacetamide. The derivatization was found to be quantitative as was the extraction of the maltol. A rate study was performed on the derivatization along with studies of temperature dependence, reagent dependence, and solvent dependence. Preliminary results show that streptomycin can be quantitatively analyzed over a wide range of concentrations and is independent of the purity of the sample.

PREPARATION OF AKLYLIDENECYCLOALKANE.

Dominic T. C. Yang, Ray Emitt, and Jim Purser, Dept. of Chemistry, UALR, Little Rock, AR 72204.

Classically the Wittig reaction has been well established as the method for the preparation of exocyclic double bonds. We wish to report an alternative method of preparing methylenecyclohexane via the reduction of 1-cyclohexene carboxylaldehyde. The following scheme is representative:



The following paper was a co-winner of the outstanding collegiate award.

PURIFICATION AND PARTIAL CHARACTERIZATION OF CALMODULIN FROM THE MYXOMYCETE *PHYSARUM FLAVICOMUM*.

Lou Ann Young and Thomas J. Lynch, Dept. of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

Calmodulin, an important cellular regulatory protein, has been identified in the plasmodium of the myxomycete *Physarum flavicomum*. Calmodulin was purified by affinity chromatography techniques using the antipsychotic drug fluphenazine as the binding ligand with Sepharose 4B as the matrix. Calmodulin binds to fluphenazine in the presence of calcium and is preferentially released upon the addition of the calcium chelator ethyleneglycol-bis (B-aminoethyl)-N,N-tetraacetic acid (EGTA). Myxomycete calmodulin appears to be similar to calmodulins isolated from higher organisms. These include its response to calcium, lack of species specificity, and molecular weight as determined by polyacrylamide gel electrophoresis.

THE EFFECTS OF PURIFIED *SALMONELLA ENTERITIDIS* ENDOTOXIN ON THE IMMUNE RESPONSE OF BALB/C MICE

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ABSTRACT

Wasting disease was produced in neonatal Balb/c mice with purified *Salmonella enteritidis* endotoxins. The endotoxins were chemically characterized to provide the study with a potent endotoxin with constant biological activity. Neonatal mice received an initial injection of 35 μg/g body weight of endotoxin and a dose of 75 μg every third day until day 18.

The degree of wasting was estimated by the runting (weight loss) index. Mortality was calculated to be 46%, with a mean survival time of approximately 15 days. The hematologic studies conducted at days 10, 20, and 30 showed an absolute neutrophilia and leukocytosis by day 10 which persisted to day 30. Immunologic data indicated that the responsiveness to sheep erythrocytes was depressed to day 20 and continued to persist at day 30. It was postulated that endotoxin either directly or indirectly affects the immune apparatus which allows the normal flora of the animal to establish an infection leading to wasting and death.

INTRODUCTION

Wasting disease is a syndrome characterized by ruffled fur, diarrhea, wrinkled and dry skin, a high stepping gait, failure to gain weight, and, in some instances, death. Wasting diseases have been produced in newborn mice by neonatal thymectomy (Miller, 1961) or by treatment with cortisol acetate (Schlesinger, 1964; Reed and Jutila, 1965) or estradiol (Reilly et al., 1967). The similarities of these diseases have caused many workers to postulate that common pathological or physiological events are responsible for the wasting and death of diseased animals.

There is considerable evidence that the microbial flora of the animal may play a major role in the development of symptoms of many forms of the disease. It was shown that germ-free mice were highly resistant to cortisol acetate-induced wasting disease (Reed and Jutila, 1965). Similarly, Wilson et al. (1964). Independently, McIntire et al. (1964) showed that thymectomized germ-free mice failed to waste in contrast to severe wasting exhibited by conventionally-reared mice thymectomized at birth.

The disease's course often has been mitigated by treatment with antibiotics. Hence, neonatally thymectomized mice treated with oxytetracycline (Azar, 1964) displayed less severe symptoms and a lower mortality than their untreated counterparts. Similarly, the antibiotic treatment of mice injected neonatally with cortisol acetate improved the clinical course and reduced the incidence of death. Thus, these observations tend to incriminate microorganisms and/or their products in the development of pathologic events that contribute to symptoms of wasting disease.

Among the normal flora isolated from tissues and organs of mice suffering from various forms of wasting diseases are several species of the *Enterobacteraceae* (Jutila and Reed, 1967; Jutila and Cantrell, 1970). A common component of gram-negative enteric bacteria is endotoxin, known to adversely influence the immune mechanism and produce pathologic changes similar to those observed in many of the wasting diseases. Since the normal microbial flora has been implicated in the pathogenesis of many forms of wasting disease, endotoxins, as products of the normal flora, were used to induce wasting in neonatal Balb/c mice.

METHODS AND MATERIALS

Inbred Balb/c mice were used throughout the study. The mice were originally obtained from the National Cancer Institute (Bethesda, Maryland) in the germ-free state and were conventionalized six months later. The mice have since been maintained by successive brother-sister matings in the Montana State University Rodent Breeding Colony. All animals received Purina Laboratory Chow and water *ad libitum*.

Endotoxin extracts were prepared from *Salmonella enteritidis*, strain S-795, (kindly supplied by Dr. E. Ribi) grown in trypticase soy broth (BBL). The endotoxin was prepared by either the dioxane or aqueous ether methods of Ribi (1958) and Fukushi et al. (1964).

The dioxane method involved the addition of 1,4 dioxane to an equal volume of 0.15 M saline containing 10 mg per ml of washed cells. The suspension was stirred at room temperature for 12 hrs and the resulting extract clarified by centrifugation at 2500 g for 70 min. The supernatant fluid was dialyzed against several changes of distilled water for six days and then lyophilized.

The aqueous ether extraction was performed by resuspending freshly harvested and washed cells in saline on the basis of turbidity (scale reading of 770 in a Klett-Summerson colorimeter, filter number 540). Two volumes of precooled (6-12° C) diethyl ether were added to the cell suspension at the same temperature and the mixture shaken for six consecutive ten-minute intervals with precaution taken to release the pressure after each interval. The suspension was left overnight at 6-12°C, after which the aqueous phase was drawn off and the residual ether removed by bubbling air through the suspension. The remaining steps were performed at 4-6°C. The residual cells were removed from the supernate containing soluble endotoxin by centrifugation at 2500 g for 70 min. The supernate was dialyzed against daily changes of distilled water for five days. NaCl was added to a final concentration of 0.15 M and the endotoxin precipitated by slowly adding absolute ethanol until a final concentration of 68% by volume was reached. After the suspension was allowed to stand at 6°C overnight, the precipitate was collected by centrifugation at 2000 g for 45 min, dissolved in the same volume of 0.15 M NaCl, and reprecipitated with ethanol. Then, the precipitate was lyophilized.

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The lyophilized preparation, after rehydration, was autoclaved at 18 pounds pressure for 15 min.

Total protein content was determined by Lowry's technique (Lowry, 1951) using bovine serum albumin to establish a standard curve. The carbohydrate determination was done by the anthrone reagent method and glucose to establish the standard curve (Morris, 1948). Lipid content was determined by a modification of the gravimetric technique by Entenman (1957).

The LD_{50} was determined by injecting one of four groups of mice intravenously (i.v.) with a given dose of endotoxin. Each group contained five adult Balb/c mice and were given the following doses: Group 1 received 100 μg per gram (μg/g) body weight; Group 2, 50 μg/g body weight; Group 3, 25 μg/g body weight; and Group 4, 12.5 μg/g body weight. The LD_{50} was determined by a modification of the Reed-Muench technique described by Carpenter (1956).

Experimental litters were sized to contain between five and eight neonatal mice of mixed sex. The average weight of these mice at the time of the initial injection was between 1.0 and 2.0 g. The initial injection was given intraperitoneally (i.p.) to animals less than 24 hrs old. The initial dose of endotoxin was 35 μg/g body weight. Subsequent doses of 75 μg of endotoxin were given i.p. every third day until day 18. The time of onset and severity of wasting was approximated by a runting index (RI) described by Keast (1968).

Blood for hematological studies was drawn from the tail or retro-orbital sinus. Differential leukocyte counts were performed on Wright's stained smears and recorded as lymphocytes, polymorphonuclear leukocytes (PMN) and monocytes. Total leukocyte counts were performed on a Model B Coulter Counter (Coulter Electronics, Hialeah, Florida). Hematocrit values were obtained by drawing blood into heparinized capillary tubes and centrifuging in an Adams Autocrit centrifuge (Clay-Adams Inc., New York).

Following sacrifice, the spleen, liver, and thymus were removed and bathed in phosphate buffered saline (PBS) until weighed. An organ index (O.I.) was calculated by a modification of the Simonsen method as follows (Simonsen, 1958):

$$\text{O.I.} = (\text{organ weight} \div \text{body weight}) \times 100$$

All animals were injected with 0.1 ml of 10% suspension of thrice-washed sheep red blood cells (SRBC) at either 10, 20, or 30 days of age. At days 5 and 10 after immunization, ten drops of tail or retro-orbital blood was collected in 0.5 ml saline and the serum removed for titering. The peak of IgM hemolysin production was presumed to occur at day 5, whereas the 10-day period approximated the peak of IgG hemagglutinating antibody (Ab) production.

Hemagglutinin titers were determined by serial two-fold dilutions of individual sera in a volume of 0.1 ml saline. To each serum dilution, 0.1 ml of a 1% SRBC suspension was added. The tubes were incubated for 30 min at 37°C and stored at 4°C overnight. The tubes were centrifuged at 3500 rpm for 1 min and the degree of agglutination scored. If agglutination occurred, the cells came up as one large clump (scored as 4), several large clumps (scored as 3), small clumps and loose cells (scored as 2), or mainly loose cells with some persistant clumps (scored as 1). In the absence of agglutination, there was a cloud of loose cell with no clumping (scored as negative). The titer was taken as the last serum dilution in the series to be scored as 1 or more.

Hemolysin titers were determined by adding 0.05 ml of guinea pig complement (BBL) diluted 1:5 to the standard hemagglutination system described above. The tubes were incubated at 37°C for 30 min and stored at 4°C overnight before reading. The last tube showing complete hemolysis was taken as the end point or titer.

RESULTS

Comparative Chemical Analysis of the Endotoxins.

Chemical analyses were performed on *S. enteritidis* endotoxin prepared by the dioxane method (designated Se-dioxane) and the aqueous ether method (Se-ether), described by Ribi (1958). The chemical composition of these endotoxins and the aqueous ether-extracted endotoxin obtained from Dr. Ribi is described in Table 1.

Table 1. Chemical composition of endotoxin prepared by the aqueous ether or dioxane method.

Endotoxin	Percent Protein	Percent Carbohydrate	Percent Lipid
Se-dioxane	42.0	7.7	N.A.[A]
Se-ether	21.0	38.7	18.0
Se-Ribi[B]	21.5	46.0	13.3

[A] Not available

[B] J. Bact. 87:391

The results show that the chemical composition of endotoxins prepared by the aqueous ether method, both Dr. Ribi's preparation and that prepared for this study, was essentially similar. A protein content of 21 and 21.5%, a hexose content of 38.7 and 47% and a lipid content of 18 and 13.3%, respectively, were determined for Barnett and Ribi endotoxin.

These results are contrasted with those obtained for Se-dioxane where protein estimates were increased to 42% and hexose content decreased to 7.7%. A lipid determination was not performed on Se-dioxane.

Characteristics of Wasting Disease.

The LD_{50} of Se-dioxane for adult Balb/c mice was 22.9 μg/g body weight. Since newborn mice tolerated this dose with few toxic symptoms, the study employed an initial dose of 35 μg/g body weight followed by one of 75 μg/g in the subsequent injections.

The time of onset and severity of wasting disease was estimated by the runting (weight loss) index calculated at various times during treatment with endotoxin. The data shown in Figures 1, 2, and 3 both describe and compare the onset and severity to the disease induced with the three endotoxin preparations. The onset of wasting was evident by the third day in every instance, and marked failure to gain weight was observed over a 12-day period. In the case of Se-dioxane (Fig. 1), weight gains were in a plateau phase between 12 and 20

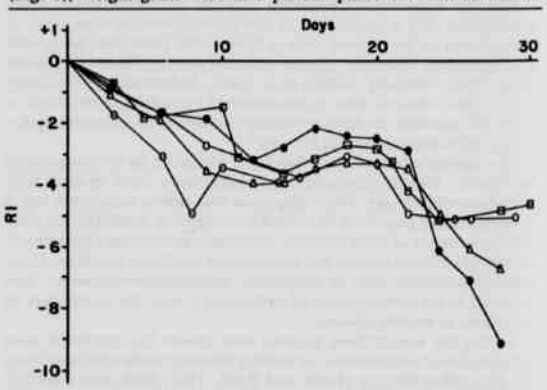

Figure 1. Runting index of Balb/c mice treated with SE-dioxane endotoxin. Newborn mice were injected with 35 μg/g body weight before 24 hours of birth and 75 μg/g of SE-dioxane every third day thereafter for 18 days. The runting index was determined by subtracting the mean weight of the control mice from the mean weight of the treated mice. Each RI unit is equal to 1 gram. Each line represents one litter.

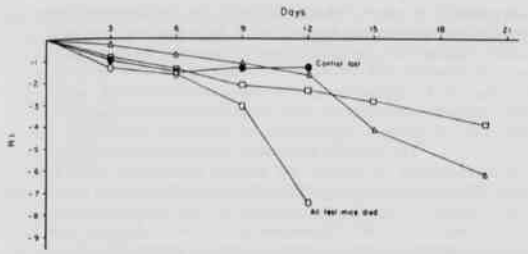

Figure 2. Runting index of Balb/c mice treated with SE-ether. Newborn mice were injected with 35 μg/g body weight before 24 hours of birth and 75 μg/g of SE-ether every third day thereafter for 18 days. The runting index was determined by subtracting the mean weight of the control mice from the mean weight of the treated miced. Each RI unit is equal to 1 gram. Each line represents one litter.

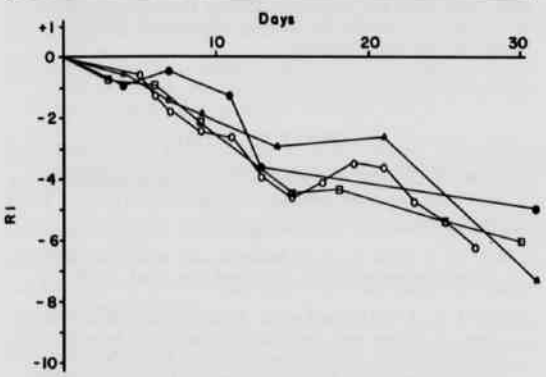

Figure 3. Runting index of Balb/c mice treated with SE-ribi. Newborn mice were injected with 35 μg/g body weight before 24 hours of birth and 75 μg/g of SE-ribi every third day thereafter for 18 days. The runting index was determined by subtracting the mean weight of the control mice from the mean weight of the treated mice. Each RI unit is equal to 1 gram. Each line represents one litter.

days, and then, following weaning, a marked failure to gain weight was again observed. Aqueous ether endotoxins generally produced a more pronounced effect on weight gain, and they were considered the more potent inducers of wasting disease. A regular finding was that a commercial endotoxin preparation, *Escherichia coli* lipopolysaccharide (Difco L.P.S.-B; *E. coli* 0111:B4 #3922), failed to induce symptoms of wasting despite the injection of comparable doses of endotoxin.

The incidence of wasting disease was found to be 100% regardless of the endotoxin employed as determined by the defined criteria (Table 2). Although, the symptoms of diarrhea and high stepping gait were not as pronounced as those seen in other forms of the disease, the failure to gain weight and other symptoms were severe. The mortality was calculated at 38% with Se-dioxane treated mice, 60% in Se-ether, and 42% in Se-Ribi treated mice. Only those mice dying later than 48 hrs after the initial injection were considered as dying from endotoxemia. Most deaths occurred during the interval from day 2 to day 25. Many mice appeared to be recovering by day 40.

Table 2. The incidence of wasting among Balb/c mice treated with endotoxin.

Endotoxin	Percent Wasting	Mean Mortality	Mean Survival Time (Days)
Se-dioxane	100	38	17.8
Se-ether	100	60	12.7
Se-Ribi	100	42	14.8
E. Coli (Difco)	0	0	--

The Effect of Endotoxin on the Hematology of Balb/c Mice.

The hematological changes during and following treatment with endotoxin are shown in Table 3. The results indicate that a pronounced leukocytosis had developed as early as day 10 and represented an increase in neutrophils. The neutrophils persisted to day 30 but the degree of shift to the left, i.e. increase in immature cell forms, could not be ascertained because of the failure to obtain total WBC's at this time. No significant differences (t-test) in the hematocrit could be detected between the control and the experimental groups for each test period. The weights of thymus, spleen, and liver of mice treated with endotoxin were nearly identical to organ weights of control mice (data not shown). The failure to obtain atrophy of thymus and spleen following treatment with endotoxin was correlated with little or no change in absolute lymphocyte counts.

Table 3. The hematology of Balb/c mice treated with multiple doses of SE-dioxane.

Treatment[a]	Day of Test	Total WBC[b]	Hematocrit	Lymphocytes	PMNs	Monocytes
Endotoxin	10	6514	52.2 0[c,d]	46.1±0.0	5.1±0.0	1.6±0.8
Control	10	4050	52±2.2	84±7.1	15±7.0	1
Endotoxin	20	9200	36±1.0[d]	49±0.0	51±0.0	0
Control	20	7319	43±4.24	64±8.5	37±2.0	1
Endotoxin	30	N.A.[e]	45±2.75	55±8.4	44±8.2	3±1.5
Control	30	N.A.	50±1.26	81±5.5	16±2.3	5±0.25

[a]Test animals received injections of endotoxin every third day from birth to day 18.
[b]All values expressed as means.
[c]Standard deviation.
[d]Not available.
[e]Not significant by the student t-test.

The Effect of Endotoxin on the Immunological Response of Balb/c Mice.

The results of the immunological studies in mice treated with Se-dioxane are presented in Table 4. The endotoxin-treated mice demonstrated a depression in both the hemolysin and the hemagglutination responses at days 20 and 30. It was observed that 68% of the experimental mice responded at day 20 to an immunizing dose of sheep erythrocytes, whereas 100% of the controls responded. Although the antibody titer of the 30-day endotoxin-treated mice had increased well above that of the 20-day old test group, apparently a severe impairment of responsiveness to sheep erythrocytes still persisted.

Table 4. The effect of multiple administration of SE-dioxane on the hemolysin and hemagglutination response in young Balb/c mice.

Treatment[a]	Days of immunization[b]	Days of titration[c]	Antibody Titers[d]					
			Hemolysin			Hemagglutination		
			No. responded[e]	Mean	Range	No. responded	Mean	Range
Endotoxin (SE-dioxane)	20	5	2/3	88	0-144	2/3	56	0-96
		10	6/9	33	0-80	5/9	52	0-160
Control	20	5	2/2	120	96-144	2/2	87	86-87
		10	2/2	75	70-80	2/2	360	80-640
Endotoxin	30	5	8/12	70	0-320	7/12	52	0-200
		10	8/11	130	0-320	9/11	148	0-320
Control	30	5	5/5	512	320-640	5/5	384	320-640
		10	5/5	240	80-320	5/5	448	320-640

[a] The mice received injections of endotoxin every third day from birth to day 18.

[b] Designates day after birth that mice were immunized with 0.1 ml of 10% sheep red blood cells i.p.

[c] Day mice were bled for antibody titrations.

[d] Titers are expressed as reciprocals of serum dilutions and the means are rounded off to the nearest whole number.

[e] The numerator designates those animals responding to immunization; the denominator the total number of animals immunized.

DISCUSSION

The symptoms of wasting disease induced with endotoxin were reminiscent of those observed with other forms of the disease, most notably, those induced with cortisol acetate (Schlesinger and Mark, 1964; Reed and Jutila, 1965) or neonatal thymectomy (Miller, 1961). Hence, it could be concluded that some of the pathological events associated with wasting induced by these methods were produced, in part, by the effects of endotoxin. The incidence of deaths among mice treated with endotoxin (Table 2) was similar to mortality among thymectomized mice treated with rabbit anti-(mouse) thymocyte serum (Jutila and Cantrell, 1970) but significantly less than the mortality among cortisol acetate treated mice (Reed and Jutila, 1965).

The hematological response of an animal treated with endotoxin was characterized by a neutrophilia which developed by day 10 and persisted through day 30 (Table 3). A similar finding was made in mice treated with cell wall preparations rich in endotoxin (Eksedt and Hayes, 1967). In contrast, the hematologic picture differs in thymectomized mice given anti-lymphocyte serum (Monaco, 1967; Agnew, 1968; Jutila and Cantrell, 1970; Jutila, 1969) and those treated with cortisol acetate (Reed and Jutila, 1967; Jutila, 1969). Thymectomized mice and neonates treated with cortisol acetate characteristically demonstrated a lymphopenia. In addition to this, Reed and Jutila (1967) observed an initial depression in the neutrophil counts after treatment with cortisol acetate; but when infections developed, a neutrophilia occurred. The discrepancy between the data obtained from mice treated with endotoxin and that obtained from thymectomized mice or mice treated with cortisol acetate may be explained by the fact that lymphocyte-producing organs such as thymus and spleen were unaffected by the treatment in one case and severely damaged or abated in the other. It seems especially pertinent that a neutrophilia, as observed in this or other forms of wasting, is commonly associated with infection.

The immunological studies on endotoxin-treated mice (Table 4) closely parallel those seen in wasting mice following thymectomy or treatment with cortisol acetate (Jutila, 1969). A depression of responsiveness to sheep erythrocytes was evident at day 20 with slight recovery at day 30 after initiation of treatment. These results confirm the findings of several investigators (Eksedt and Nishimura, 1964; Eksedt and Hayes, 1967; Chester et al., 1971; Diamantstein et al., 1976; and Nakano et al., 1976) who also demonstrated an impaired antibody response in endotoxin-treated mice. Of interest is the observation by Eksedt and Hayes (1967) that although no circulating antibody to sheep erythrocytes could be detected, the mechanism for rejecting skin grafts was not affected. This result would indicate that although the humoral immune response was impaired, the cellular response was unaffected. It also emphasized the well-known dichotomy between the two systems. The precise reasons for antibody suppression were not determined; however, this effect probably occurred during the induction phase of the immune response. In support of this postulate it was noted that although the lymphocyte counts and morphology appeared to be unaffected, little antibody was being produced. Apparently, the antigen was prevented from reacting with the antigen sensitive cell. Precisely how this effect may be mediated is not known, but it may occur in one of the following ways: The endotoxin may cause an adrenal hyperreactivity which, in turn, provokes the production and release of abundant steroids (L. Hayes, *pers. comm.*). The steroids, because of their predilection for lymphoid tissue, eliminate or damage the antigen recognition units (Miller, 1967; Mitchell and Miller, 1968). Alternatively, steroids may inhibit the lysosome-mediated transformation of the responsive lymphocyte (Hischhorn et al., 1967; Weissmann et al., 1967). Another possibility is that endotoxin, with its interaction with lymphoid cells, directly rather than indirectly, interferes with or damages the unit for antigen recognition.

Immunological suppression in wasting animals may be a necessary prerequisite to the events that kill the animal. It has been demonstrated that symptoms of and death from wasting disease are caused by an infectious process following impairment of the immune mechanism of the animal (Jutila and Cantrell, 1970; Jutila and Reed, 1968; Jutila, 1969; and Azar, 1964, 1964b). The depression allows the normal flora to invade the body of the animal, causing wasting disease induced with endotoxin.

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THE PENTATOMIDAE OF ARKANSAS

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ABSTRACT

A total of 30 genera and 53 species and subspecies of Pentatomidae are reported as occurring or possibly occurring in Arkansas. Fifty species and subspecies contained in 29 genera were collected or recorded from previously collected material. Based on distributional records in the literature, three additional species and one genus are listed as probably occurring in Arkansas. County and seasonal records are reported for each taxon.

INTRODUCTION

Important taxonomic studies dealing with Heteroptera of North America include those by Blatchley (1926) and Torre-Bueno (1939). Early research efforts concentrating on Pentatomoidea (= Scutelleroidea) of state-wide areas were reported by Hart (1919) for Illinois and Stoner (1920) for Iowa. Later similar investigations were contributed by Froeschner (1941) for Missouri, McPherson (1970, 1979a) for Michigan, Hoffman (1971) for Virginia, and Furth (1974) for Ohio. The distribution of Pentatomoidea as listed by Van Duzee (1917) for the northeastern United States was updated by McPherson (1980). McPherson (1979b) also updated Hart's (1919) list of Pentatomoidea occurring in Illinois. References to Arkansas pentatomids are scarce and apparently no previous studies have been concentrated in this area. This paper summarizes current information on number of species, seasonal occurrence, and geographical distribution of Pentatomidae in Arkansas.

METHODS AND MATERIALS

Data are primarily based on results obtained from intensive collecting throughout the state in 1979 and 1980. Areas of the state most intensively surveyed were north central, northeast, and Crowley's Ridge (extending from Clay County southward to Phillips County). Although collecting efforts in other parts of the state were less intensive, we feel that the species listed accurately reflect the pentatomid occurrence in the state.

Additional records were obtained from entomological holdings at the University of Arkansas at Fayetteville, the University of Arkansas at Little Rock, Memphis State University, and Arkansas State University. A total of 50 species and subspecies are recorded from the state, contained in 29 genera and four subfamilies. Three additional species and one genus are listed as probably occurring in Arkansas because of their known distributions.

For this study, we have followed the taxonomic scheme of Rolston and McDonald (1979) in which the Pentatomidae are divided into five subfamilies; Asopinae, Discocephalinae, Edessinae, Pentatominae, and Podopinae, four of which are represented in Arkansas (Asopinae, Edessinae, Pentatominae, and Podopinae). With further research providing a more comprehensive Heteroptera collection for Arkansas, some additions to records will undoubtedly be made.

RESULTS AND DISCUSSION

Species distributions are shown in Figs. 2-28, with the months that each species was collected indicated in the species list. Figure 1 pro vides a key to the Arkansas counties.

Species List

Asopinae

Alcaeorrhynchus grandis (Dall.). Two specimens (one each from University of Arkansas at Fayetteville and University of Arkansas at Little Rock insect collections) were examined. Due to the known distribution of this species (Blatchley, 1926), we suspect these specimens may have been transported accidentally into the state.

Apateticus cynicus (Say). Fig. 2. June, September.

Euthyrhynchus floridanus (L.). Fig. 2. June-November.

Perillus bioculatus (Fab.). Fig. 3. August, November.

Perillus circumcinctus Stal. Froeschner (1941) reported that this species should occur throughout the state of Missouri. We believe that it probably occurs at least in northern Arkansas.

Podisus maculiventris (Say). Fig. 9. February, April-August, October-December.

Podisus placidus Uhler. Fig. 4. January, July, September.

Stiretrus anchorago (Fab.). Fig. 5. June-October.

Edessinae

Edessa bifida (Say). Fig. 14. September.

Pentatominae

Acrosternum hilare (Say). Fig. 6. March-November.

Acrosternum pennsylvanicum (De Geer). Slater and Baranowski (1978) reported this species as being widely distributed from Quebec west to Iowa and south to Florida. It probably will be found in Arkansas.

Aelia americana Dall. Fig. 7. February, April, November.

Banasa dimidiata (Say). Fig. 8. March-July, November.

Banasa euchlora Stal. Fig. 8. April, June-December.

Brochymena arborea (Say). Fig. 10. April-July, September-November.

Brochymena cariosa Stal. Fig. 10. January, February, April-June, September-December.

Brochymena carolinensis (Westwood). Fig. 11. April-June, October, December.

Brochymena punctata Van Duzee. Fig. 11. August.

Brochymena quadripustulata (Fab.). Fig. 12. January-July, September-December.

Chlorochroa ligata (Say). Fig. 23. August.

Chlorochroa persimilis Horvath. Fig. 26. April, June.

Chlorochroa sayi (Stal). Fig. 13. September, December.

Coenus delius Say. Fig. 13. July, September.

Coenus inermis Harr. and John. Fig. 13. June.

Cosmopepla bimaculata (Thom.). Fig. 11. July-October.

Dendrocoris humeralis (Uhler). Fig. 11. April, June, September.

Euschistus ictericus (L.). Fig. 14. May-July, October.

Euschistus politus Uhler. Fig. 14. June, July.

Euschistus servus servus (Say) - *E. s. euschistoides* (Voll.), intergrade populations. Fig. 15. February, April-November.

Euschistus tristigmus tristigmus (Say). Fig. 16. March-November.

Euschistus variolarius (Palisot de Beauvois). Fig. 17. April-August.

Holcostethus limbolarius Stal. Fig. 18. April-July, September-December.

Hymenarcys aequalis (Say). Fig. 17. March, April, August, December.

Hymenarcys nervosa (Say). Fig. 19. January, February, April-November.

Mecidea major Sailer. Fig. 20. October.

Mecidea minor Ruckes. Fig. 20. June, September, October.

Menecles insertus (Say). Fig. 21. February, April, May, July, October-December.

Mormidea lugens (Fab.). Fig. 22. April-October.

Murgantia histrionica (Hahn). Fig. 21. March-May, July-November.

Neottiglossa cavifrons Stal. Fig. 23. January-July.

Neottiglossa coronaciliata Ruckes. Fig. 24. May.

Neottiglossa sulcifrons Stal. Fig. 24. February, April-August.

Nezara viridula (L.). Fig. 3. June-December.

Oebalus pugnax pugnax (Fab.). Fig. 25. April-December.

Prionosoma podopioides Uhler. Froeschner (1941) reported this species as probably occurring over much of Missouri. It may be found in northern Arkansas.

Proxys punctulatus (Palisot de Beauvois). Fig. 26. June-November.

Thyanta accerra McAtee. Fig. 27. February-November.

Thyanta antiguensis (Westwood). Fig. 13. May.

Thyanta calceata (Say). Fig. 28. February-December.

Thyanta custator (Fab.). Fig. 4. October.

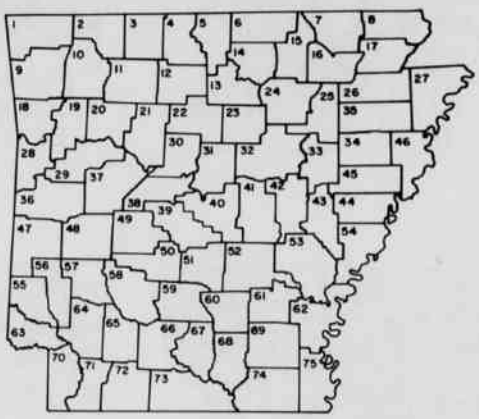
Thyanta punctiventris Van Duzee. Fig. 4. August.

Trichopepla semivittata (Say). Fig. 7. April-November.

Podopinae

Amaurochrous cinctipes (Say). Fig. 4. June.

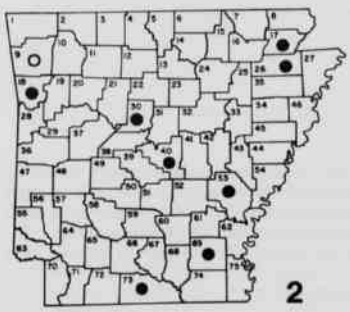
More research of local insect populations is needed to aid our understanding of distributional patterns, ecological relationships, and taxonomic status of the many lesser known species. For example, the Pentatomidae and allied families (Acanthosomatidae, Corimelaenidae, Cydnidae, and Scutelleridae) constitute a group of insects which is important to man, yet relatively little is known about the food habits, life histories, and systematics of many species in this group. Some of the Arkansas pentatomids that are economically destructive are *Oebalus pugnax pugnax* (Fab.), the rice stink bug; *Murgantia histrionica* (Hahn), the harlequin bug; *Euschistus servus* (Say), the brown stink bug; and *Nezara viridula* (L.), the southern green stink bug. *Oebalus p. pugnax* is destructive to rice, wheat, and sorghums, all of which are grown extensively in Arkansas. *Murgantia histrionica* invades cabbage and other cruciferous crops in the southern United States (Borror, et al., 1976), and *E. servus* is injurious to cotton (Slater and Baranowski, 1978). *Nezara viridula* feeds on various crops, including soybeans and clovers. Many species of Asopinae are considered to be beneficial because they prey on other insects. The most commonly occurring Arkansas species in this group is the spined soldier bug, *Podisus maculiventris* (Say).

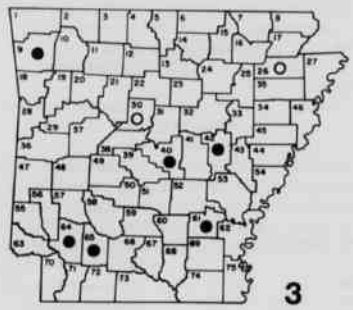


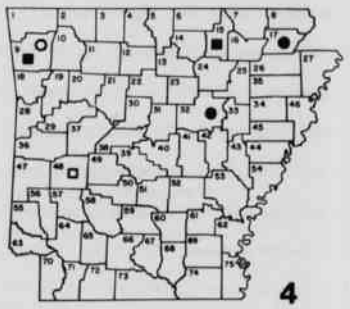
ARKANSAS COUNTIES

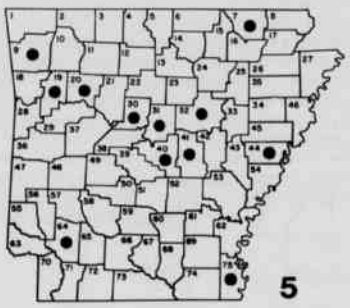
1. Benton	20. Johnson	39. Saline	58. Clark
2. Carroll	21. Pope	40. Pulaski	59. Dallas
3. Boone	22. Van Buren	41. Lonoke	60. Cleveland
4. Marion	23. Cleburne	42. Prairie	61. Lincoln
5. Baxter	24. Independence	43. Monroe	62. Desha
6. Fulton	25. Jackson	44. Lee	63. Little River
7. Randolph	26. Craighead	45. St. Francis	64. Hempstead
8. Clay	27. Mississippi	46. Crittenden	65. Nevada
9. Washington	28. Sebastian	47. Polk	66. Ouachita
10. Madison	29. Logan	48. Montgomery	67. Calhoun
11. Newton	30. Conway	49. Garland	68. Bradley
12. Searcy	31. Faulkner	50. Hot Spring	69. Drew
13. Stone	32. White	51. Grant	70. Miller
14. Izard	33. Woodruff	52. Jefferson	71. Lafayette
15. Sharp	34. Cross	53. Arkansas	72. Columbia
16. Lawrence	35. Poinsett	54. Phillips	73. Union
17. Greene	36. Scott	55. Sevier	74. Ashley
18. Crawford	37. Yell	56. Howard	75. Chicot
19. Franklin	38. Perry	57. Pike	

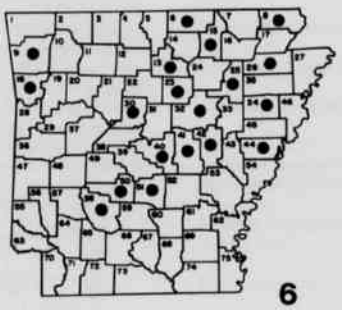
Fig. 1. The counties of Arkansas.

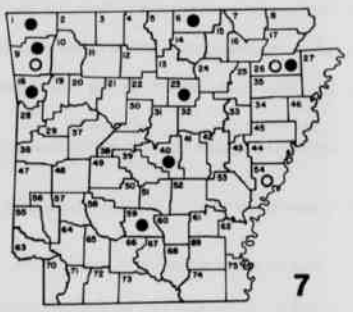


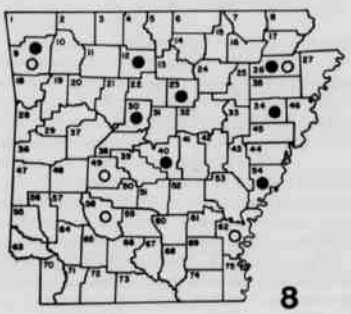


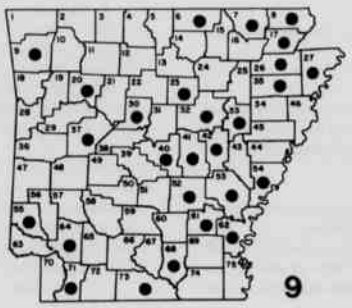












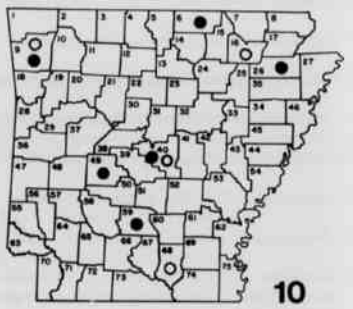


PLATE I

Fig. 2. *Apateticus cynicus* (O) and *Euthyrhynchus floridanus* (●).

Fig. 3. *Perillus bioculatus* (O) and *Nezara viridula* (●).

Fig. 4. *Amaurochrous cinctipes* (□), *Podisus placidus* (■), *Thyanta punctiventris* (O), and *Thyanta custator* (●).

Fig. 5. *Stiretrus anchorago.*

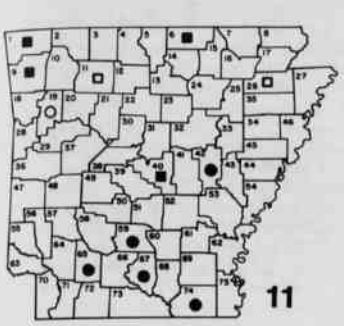
Fig. 6. *Acrosternum hilare.*

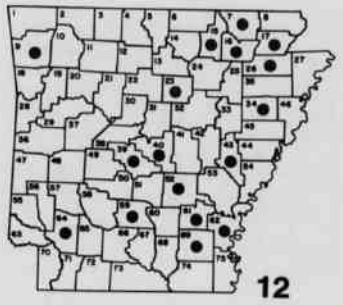
Fig. 7. *Aeila americana* (O) and *Trichopepla semivittata* (●).

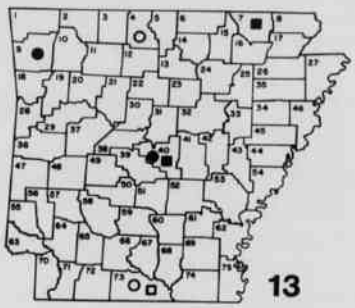
Fig. 8. *Banasa dimidiata* (O) and *Banasa euchlora* (●).

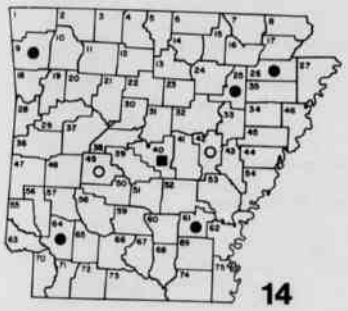
Fig. 9. *Podisus maculiventris.*

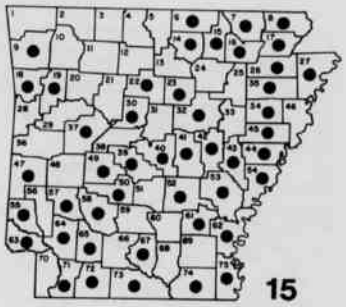
Fig. 10. *Brochymena arborea* (O) and *Brochymena cariosa* (●).

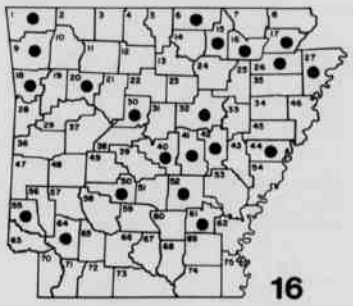


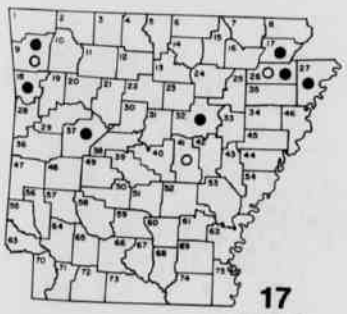


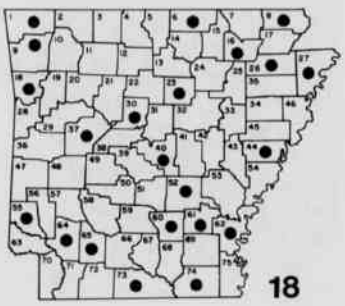












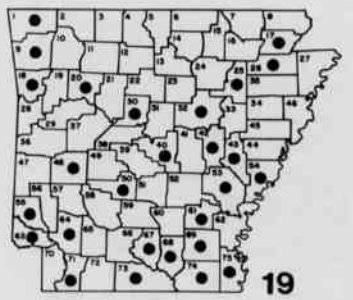


PLATE II

Fig. 11. *Brochymena punctata* (O), *Brochymena carolinensis* (●), *Dendrocoris humeralis* (□), and *Cosmopepla bimaculata* (■).

Fig. 12. *Brochymena quadripustulata.*

Fig. 13. *Coenus inermis* (O), *Coenus delius* (●), *Thyanta antiguensis* (□), and *Chlorochroa sayi* (■).

Fig. 14. *Euschistus politus* (O), *Euschistus ictericus* (●), and *Edessa bifida* (■).

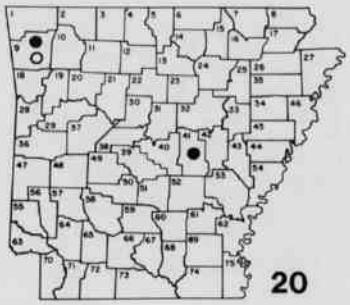
Fig. 15. *Euschistus servus servus-E. s. euschistoides,* intergrade populations.

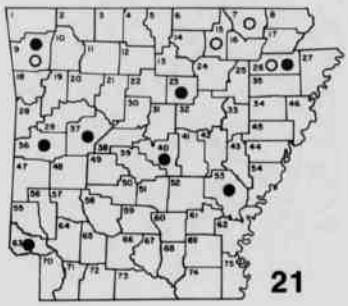
Fig. 16. *Euschistus tristigmus tristigmus.*

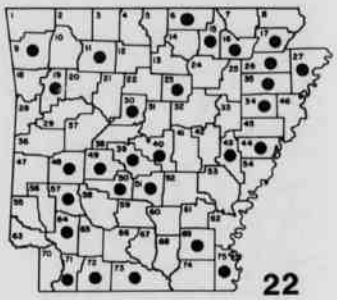
Fig. 17. *Hymenarcys aequalis* (O) and *Euschistus variolarius* (●).

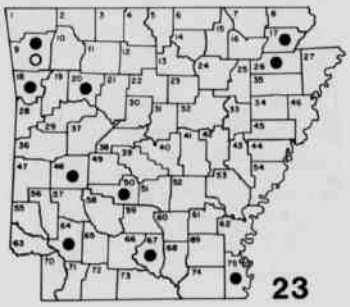
Fig. 18. *Holcostethus limbolarius.*

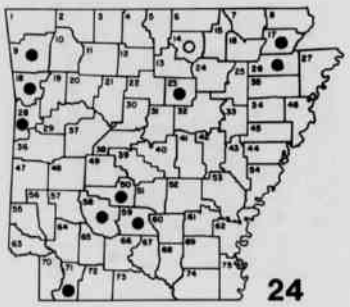
Fig. 19. *Hymenarcys nervosa.*

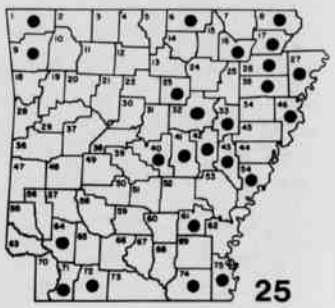


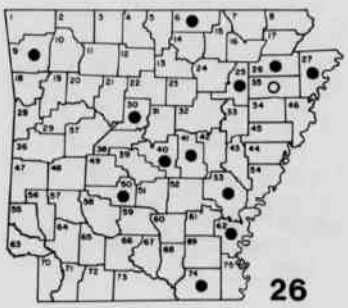


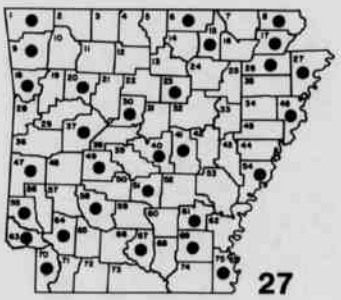












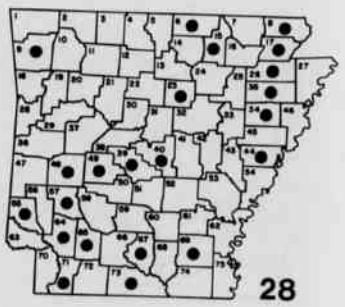


PLATE III

Fig. 20. *Mecidea major* (O) and *Mecidea minor* (●).

Fig. 21. *Menecles insertus* (O) and *Murgantia histrionica* (●).

Fig. 22. *Mormidea lugens*.

Fig. 23. *Chlorochroa ligata* (O) and *Neottiglossa cavifrons* (●).

Fig. 24. *Neottiglossa coronaciliata* (O) and *Neottiglossa sulcifrons* (●).

Fig. 25. *Oebalus pugnax pugnax*.

Fig. 26. *Chlorochroa persimilis* (O) and *Proxys punctulatus* (●).

Fig. 27. *Thyanta accerra*.

Fig. 28. *Thyanta calceata*.

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MICROHABITAT DISTRIBUTION AND ITS EFFECT ON PREY UTILIZATION IN SYMPATRIC POPULATIONS OF *PLETHODON GLUTINOSUS* AND *PLETHODON DORSALIS* IN NORTHWESTERN ARKANSAS

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ABSTRACT

A study was done on sympatric populations of *Plethodon glutinosus* and *P. dorsalis* in northwestern Arkansas to determine the relative distribution of the two species and the relationship between their distribution and the utilization of available prey. Upon capture, total length, location, and habitat type were recorded for each salamander. Stomach content samples were obtained by forced regurgitation, and the animals were released. Samples of the local litter fauna were taken to determine prey availability. Habitat data were obtained for 171 salamanders; 76 *P. glutinosus* and 95 *P. dorsalis*. Stomach content samples were taken from 67 salamanders; 32 *P. glutinosus* and 35 *P. dorsalis*. An apparent relationship was found between environment and utilization of certain prey taxa. Prey related factors, such as relative size of prey and salamander, were also found to affect utilization. Both species were euryphagic.

INTRODUCTION

Plethodon glutinosus and *P. dorsalis* are two of the most widely distributed species in the family Plethodontidae. Sympatric populations of these species have been found in many localities including northwestern Georgia (Martof, 1956), Tennessee (King, 1939; Parker, 1939), Kentucky (Burt, 1933), and the Ozark Plateau in northeastern Oklahoma (Bragg and Hudson, 1951) and northwestern Arkansas (Spotila, 1972). Studies of ecological relationships between sympatric populations of plethodontid salamanders are numerous (e.g. Dumas, 1956; Fraser, 1976a, 1976b; Jaeger, 1972, 1974a, 1974b; Powders and Tietjen, 1974). However, the relative distributions of and ecological relationships between sympatric populations of *P. glutinosus* and *P. dorsalis* have never been reported. The object of this study was to determine the relative distribution of these species in an area of sympatry and to determine the effect of the observed distribution on the utilization of available prey.

METHODS AND MATERIALS

The study area is near Lake Wedington, 21 km west of Fayetteville, Washington County, Arkansas, on Highway 16. The site is in the valley of a small stream on the edge of a plateau of Boone formation limestone which is gradually eroding down to the level of the Illinois River (geological determination courtesy of Charles Britton, petroleum geologist for Texas Oil & Gas, OKC). The Boone formation limestone is very friable and heavily fractured. There is considerable solution activity producing many small caves and the narrow, steep valleys typical of Karst topography. The topsoil is generally thin and often nonexistent, the substrate seldom being any less than 50% talus. The vegetation on the site consists of Oak-Hickory forest, which is characteristic of mesic north facing slopes in the area.

Field work was carried out at the study site from 17 March to 12 May 1979. The habitat was divided into two general categories, seepage areas where the substrate was normally saturated at that season, and drier hillside. After each salamander was captured, location (including shelter and substrate type), habitat type, and total length were recorded. Stomach content samples were taken, after which the animals generally were released. Samples of the surface litter were taken from four 50cm x 50cm quadrates chosen at random in each habitat to determine prey availability. All litter and topsoil down to the level of the talus substrate was collected and placed in sealed plastic bags.

Stomach content samples were obtained by forced regurgitation. A syringe equipped with a flexible plastic tube 1mm in diameter and 100mm in length was inserted down the esophagus and into the stomach. One to 4cc of water was then injected, causing immediate regurgitation. Stomach content samples were obtained from salamanders as small as 30mm. Samples were preserved in 50% EtOH and were brought to the lab for counting.

In the lab, litter samples were placed in Berlese funnels, and invertebrates recovered were preserved in 50% EtOH. Berlese samples were counted by placing a portion of the sample in a petri dish and scanning with a dissecting microscope. All invertebrates were removed, classified, counted, and placed in clean 50% EtOH. Each successive portion was counted in this manner until the entire sample had been examined. Stomach content samples were counted in the same manner.

RESULTS

The population of *Plethodon dorsalis* was concentrated in the seepage areas (85.4% of captures), with captures on the drier hillsides being rare (14.6%). In contrast, *Plethodon glutinosus* was nearly equally distributed in the two habitats (42% seepage, 58% hillside). *P. dorsalis* was rarely captured more than 6.2 m above stream level, while *P. glutinosus* was commonly found up to 10.5-12.2 m above stream level. Both species were more abundant on the valley floor and lower slopes than above 6.2 m, especially in the seepage areas.

The mean lengths for *P. glutinosus* and *P. dorsalis* collected in the seepage areas were 70.7mm ± 5.0mm (N=27) and 57.5mm ± 3.7mm (N=32), respectively. The corresponding figures for hillside environments were 112.5mm ± 5.6mm (N=32) and 66.8mm ± 4.6mm (N=13), respectively. Individuals with partially amputated tails were omitted from the calculations. When tested for significance using a one-tailed t-test for comparison of means of unequal samples, the difference was found to be highly significant in *P. glutinosus* and not significant in *P. dorsalis* (*P. glutinosus* $t=5.47$, $t_{.01(58)}=2.393$; *P. dorsalis* $t=1.45$, $t_{.05(44)}=1.681$). It is my feeling that the combination of low sample size and incidental occurrence of two very small *P.*

Table 1. Results of litter sampling.

Taxon	SEEPAGE #/m²	f	%Ts	HILLSIDE #/m²	f	%Th	%s	Tc	%Tc
Annelida	50	100	1.6	35	100	1.0	58.8	85	1.1
Gastropoda	17	100	0.6	23	100	0.5	42.5	40	0.5
Isopoda	67	100	2.2	0	0	0	100	67	0.9
Copepoda	30	50	1.0	0	0	0	100	30	0.4
Myriopoda	7	75	0.2	20	100	0.5	25.9	27	0.4
Pseudoscorpionida	18	100	0.6	71	100	1.7	20.2	89	1.2
Aranieda	31	100	1.0	41	100	1.0	43.1	72	1.0
Acarina	1589	100	51.9	2137	100	49.0	42.6	3726	50.2
Collembola	1032	100	33.7	1232	100	28.2	41.6	2264	30.5
Thysanoptera	12	25	0.4	89	100	2.0	11.9	101	1.4
Lepidoptera	3	50	0.1	28	100	0.6	9.7	31	0.4
Trichoptera	0	0	0	0	0	0	0	0	0
Homoptera	5	50	0.2	3	50	0.1	62.5	8	0.1
Hemiptera	2	50	0.1	5	50	0.1	28.6	7	0.1
Diptera	81	100	2.6	58	100	1.3	58.3	139	1.9
Hymenoptera	22	100	0.7	571	100	13.1	3.7	593	8.0
Coleoptera	90	100	2.9	48	100	1.1	64.5	138	1.9
Urodela	4	50	0.1	1	25	0.02	80.0	5	0.1
Total	3060			4362				7422	

#/m² = number of organisms per square meter
f = percent frequency of occurrence of organism in samples
%Ts = numerical percent of total seepage sample
%Th = numerical percent of total hillside sample
%s = percent of total number of organisms (seepage plus hillside) occurring in the seepage samples
Tc = combined total (seepage plus hillside)
%Tc = numerical percent of combined total
(Copepoda were included in the data as an indicator of the degree of saturation of the seepage areas, but they were not considered as a prey item)

Table 2. Results of stomach content sampling.

Taxon	*P. dorsalis* Ns=26-s, Ns=9-h #s	f	%Ts	#h	f	%Th	Tc	%Tc	*P. glutinosus* Ns=3-s, Ns=29-h #s	f	%Ts	#h	f	%Th	Tc	%Tc
Annelida	7	29.1	2.8	0	0	0	7	1.8	0	0	0	8	20.7	3.7	8	3.3
Gastropoda	4	15.4	1.6	5	11.1	3.4	9	2.3	0	0	0	4	27.5	4.1	9	3.7
Isopoda	13	30.8	5.2	2	11.1	1.4	15	3.8	22	100	81.5	24	44.8	11.1	46	19.0
Myriopoda	1	3.8	0.4	3	33.3	2.1	4	1.0	0	0	0	13	31.0	6.0	13	5.4
Pseudoscorpionida	1	3.8	0.4	0	0	0	1	0.3	0	0	0	2	6.9	1.0	2	0.8
Aranieda	3	11.5	1.2	0	0	0	3	0.8	0	0	0	16	41.4	7.4	16	6.6
Acarina	39	46.2	15.7	22	77.8	15.2	61	15.5	0	0	0	9	17.2	4.2	9	3.7
Collembola	28	38.5	11.3	32	66.6	22.1	60	15.3	1	33.3	3.7	8	20.7	3.7	9	3.7
Thysanoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	3	11.5	1.2	0	0	0	3	0.8	0	0	0	4	13.8	1.9	4	1.7
Trichoptera	6	19.2	2.4	2	22.2	1.4	8	2.0	0	0	0	1	3.4	0.5	1	0.4
Homoptera	1	3.8	0.4	0	0	0	1	0.3	0	0	0	0	0	0	0	0
Hemiptera	1	3.8	0.4	0	0	0	1	0.3	0	0	0	0	0	0	0	0
Diptera	40	61.5	16.1	9	44.4	6.2	49	12.5	1	33.3	3.7	19	44.8	8.8	20	8.3
Hymenoptera	81	65.4	32.7	44	100	44.1	143	36.9	3	66.6	11.1	80	79.3	37.2	83	34.3
Coleoptera	20	46.2	8.1	6	58.5	6.1	26	6.6	0	0	0	22	44.8	10.2	22	9.1
Total	248			145			393		27			215			242	

N = number of stomach content samples (s = seepage, h = hillside)
#s = number of organisms from salamanders collected in seepage habitats
#h = number of organisms from salamanders collected in hillside habitats
f = percent frequency of organism in samples
%Ts = numerical percent of total number of organisms from salamanders collected in seepage habitats
%Th = numerical percent of total number of organisms from salamanders collected in hillside habitats
Tc = combined total (seepage plus hillside)
%Tc = numerical percent of combined total

dorsalis outside seepages on days following heavy rains caused the non-significant value in *P. dorsalis*.

Results of litter sampling are shown in Table 1. Sampling of the litter, including topsoil when present, was thought to be sufficient to obtain a valid sample of the food available to salamanders, since Fraser (1976b) found that plethodontid salamanders do virtually no feeding below the A horizon (litter plus topsoil).

The basic dichotomy in environment between seepage and hillside is evident from the distribution of the various taxonomic groups in the two environments. Some groups were restricted wholly or mainly to the seepages (Copepoda, Isopoda, Coleoptera, Urodela); while the opposite was true of other groups (Myriopoda, Pseudoscorpionida, Thysanoptera, Lepidoptera, Hymenoptera). The same was true for some subgroups within the larger taxonomic groups (e.g. Staphylinidae and Ptiliidae, Coleoptera; Psychodidae and Tabanidae, Diptera were wholly or in part restricted to seepage areas). Five salamanders were captured in the litter samples, all *P. dorsalis*; four in the seepage samples and one in the hillside samples.

The stomach content samples taken from 35 *P. dorsalis* and 32 *P. glutinosus* indicate that these species are euryphagic (Table 2). The Thysanoptera were the only group found in the litter samples and not in the stomach samples. Trichoptera were found in the stomach samples and not in the litter samples, presumably because of their inability to negotiate the Berlese funnel.

The data show clearly the effect of habitat on prey selection. Groups which are more abundant in a particular habitat tend to make up a larger proportion of the salamanders' prey in that habitat. For example, Hymenoptera represent 0.7% of the invertebrate population in the seepage areas and constitute 32.7% and 11.1% of the diets of *P. dorsalis* and *P. glutinosus*, respectively, in those areas. In the hillside areas, Hymenoptera represent 13.1% of the invertebrate population and constitute 44.1% and 37.2% of the diets of *P. dorsalis* and *P. glutinosus*, respectively. The Myriopoda show a similar trend, while the Isopoda and Trichoptera illustrate the opposite trend.

DISCUSSION

The xeric nature of the upper slopes, which, due to the highly porous nature of the substrate, become dry rapidly even after heavy rain presumably restricts both species to a certain degree to the more mesic valley floor. The data indicate that salamanders found in hillside environments tend to be larger than those found in seepage environments. This trend might reflect a capacity on the part of larger individuals to resist dessication and therefore compete more effectively in drier areas. This problem deserves further study.

Previous workers generally have found terrestrial plethodontid species to be euryphagous (e.g. Dumas, 1956; Fraser, 1976a, 1976b; Hairston, 1949; Jaeger, 1972; Powders and Tietjen, 1974; Whitaker and Rubin, 1971). The data presented support these findings. Holman (1955) found the fall and winter food of *P. dorsalis* to consist mainly of spiders, but attributed this to seasonal availability.

The data show trends indicating a probable effect of habitat on prey selection, but undoubtedly, other factors influence this activity. Fraser (1976a) found a correlation between the size of a salamander, as expressed in the width of the jaws, and the size of its prey. These data indicate that the larger, more robust *P. glutinosus* makes much less use of Acarina and Collembola (both relatively small) as prey, each constituting 3.7% of total prey items, than does *P. dorsalis*

(Acarina 15.5%, Collembola 15.2%). Avoidance on the part of the prey (or lack of it) and distribution of prey in the habitat probably influence selection as well.

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FLYING INSECT POPULATIONS AS SAMPLED BY MALAISE TRAP ON CROWLEY'S RIDGE IN NORTHEAST ARKANSAS

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ABSTRACT

Malaise trap collections from woodlot and open field sampling sites on Crowley's Ridge yielded 10,830 individuals during the months of May, July and September, 1980. Greatest numbers of insects were collected in May, with fewest in September. Four orders comprised 97% of the total catch: Diptera (57%), Lepidoptera (17%), Hymenoptera (15%) and Homoptera (8%). Coleoptera, Hemiptera, Neuroptera, Odonata and Orthoptera comprised the remaining 3%. Ordinal composition and seasonal occurrence patterns are discussed and compared for the two sampling sites.

INTRODUCTION

The Malaise trap as described by Townes (1962) is a relatively unbiased collecting apparatus for flying insects and renders itself as a useful tool for surveying flying insect populations. The trap utilizes no attracting devices and takes advantage of an insect's natural tendency to fly or crawl upward when trying to escape, thus directing it into a collecting container at the top of the trap (Breeland and Pickard, 1965).

Previous studies by Matthews and Matthews (1970, 1971) found the Malaise trap an efficient means of sampling flying insect populations for faunal composition and seasonal occurrence patterns. The Malaise trap has proven also to be useful for sampling specific dipteran populations such as Tabanidae (Roberts, 1971) and Culicidae (Breeland and Pickard, 1965). Covell (1979) and Walker (1978) found the trap to be effective for sampling lepidopteran populations as did Townes (1962) for hymenopterans.

Crowley's Ridge provides an appropriate study site as a natural division of Arkansas, geographically isolated as it rises out of the Mississippi embayment surrounded by delta lowlands. The flying insect populations of this area have not previously been surveyed.

Two adjacent but separate ecological communities (a woodlot and an open field) were utilized as collecting sites for this study. The ordinal and seasonal occurrence patterns for the Malaise trap catches at these locations are compared and discussed.

METHODS AND MATERIALS

This investigation was conducted during the months of May, July and September, 1980, on the Arkansas State University dairy farm in Craighead County, Arkansas.

The woodlot community was composed primarily of *Carya*, *Quercus* and *Ulmus* species. *Cornus* and other less abundant species were present as understory. The woodlot was bordered on the south by a stock pond. An area with sparse understory was chosen for Malaise trap placement to provide relatively unobstructed insect flyways.

The open field community was located adjacent to the woodlot on the east. It consisted of a grassland area primarily composed of *Panicum*, *Setaria* and *Sorghum* species along with less abundant flowering plant species.

The Malaise trap used for this study was a commercially purchased, square trap with a 2.44 m center support. Four central vanes directed the flying insects into the collecting head at the top of the trap which contained a 2,2-dichlorovinyl dimethyl phosphate Shell No-Pest® Strip as the killing agent.

Collecting periods of 24 hr duration were conducted once each week at each study site. The trap was emptied at 6 hr intervals from 12 p.m. to 12 p.m. the following day. Six-hour samples were sorted and identified to the family level.

Weather data, recorded by the Jonesboro Flight Station located approximately 2.14 km from the collecting sites, was obtained for each 24 hr. period and is summarized in Table 1.

RESULTS AND DISCUSSION

A total of 10,830 insect specimens representing 79 families in nine orders was collected during the 12 weeks of this study. Four orders (Diptera, Lepidoptera, Hymenoptera and Homoptera) comprised 97% of the total catch. Diptera were the most commonly collected representing 57% of the total number, followed by Lepidoptera (17%), Hymenoptera (15%) and Homoptera (8%). The combined Coleoptera, Hemiptera, Neuroptera, Odonata and Orthoptera collections formed the remaining 3% of the catch.

Diptera were represented by 24 families with 15 of these comprising at least 1% of the total ordinal composition during one of the three collecting periods. The percentage of major families of dipterans collected is shown in Table 2.

The dipterans collected were primarily nematocerous. Chironomidae and Psychodidae were collected in large numbers in the woodlot during May and September. Although less abundant, Chironomidae were predominantly collected in the open field community during July. Tipulidae were abundant in May and were taken in nearly equal numbers at both collecting sites.

As a group, brachycerous dipterans were collected in relatively low numbers. Tabanidae occurred in greatest numbers during July and September in the open field.

Cyclorrhaphous dipterans were best represented by Tachinidae, Phoridae and Muscidae. Tachinidae were present in sizeable numbers in the open field during May and September but reached their greatest population levels in both communities in July, comprising the bulk of the dipteran population for the month. The Phoridae and Muscidae were collected in considerably lower numbers but also reached their peak in mid-summer.

Table 1. Weather data for the three collecting periods.

Month (1980)	Mean Temperature Max. C.	Min. C.	Total Rainfall (mm)	Mean Relative Humidity
May	27.2	14.3	87.9	52%
July	36.6	23.5	1.0	40%
September	23.5	16.0	107.9	80%

Although Culicidae and Tabanidae were numerous in the vicinity of the trap sites, they were not collected in large numbers (Table 2). This finding is in agreement with the results of studies conducted by Matthews and Matthews (1970). Breeland and Pickard (1965) and Roberts (1971, 1972) found the Malaise trap to be highly effective for trapping these two families. However, the traps they used were modified to help influence the collection of Tabanidae and Culicidae. Roberts (1970a, 1970b, 1972, 1975, 1978) found that trap size and shape, baffel arrangement, color and other factors could significantly influence numbers of Tabanidae collected.

The percentage of major families of lepidopterans collected at both sites is shown in Table 3. The lepidopteran population was primarily composed of the family Pyralidae, which was taken in large numbers from both communities throughout the study. The Pyralidae were most abundant in the woodlot, especially in July, and were at their lowest numbers in late season. Adults of the family Noctuidae were collected in considerably smaller numbers, but with similar success, in both communities. Skippers (Hesperiidae) increased in numbers during September in both the woodlot and the open field communities. This may be attributable to seasonal migration. Studies by Covell (1979) show that several species of skippers may be collected in relatively large numbers from August to October. Lycaenidae were collected primarily in May and September with preference being shown for the open field community.

Ichneumonidae was the predominant family collected of the ten major ones of Hymenoptera, represented by percent composition in Table 4. The ichneumonids were collected in greatest numbers in the woodlot during May. Numbers of collected individuals began to decrease and level off to approximately equal ratios by mid-summer in both communities. Halictidae and Formicidae also were collected in considerable numbers. Halictidae reached their peak level in the open field throughout September. Formicidae were present in large numbers in the open field during May and July but reached their largest percentage of the hymenopteran population in September in the woodlot. The other major families were collected in smaller, but relatively constant, numbers and tended not to show a distinct preference for a particular community.

Homopterans were represented by four families with the two major families being Aphididae and Cicadellidae (Table 5). Aphids showed a preference for the woodlot during May and July but were not collected in recordable percentages from either community during September. Cicadellidae comprised the bulk of the homopteran population and maintained an almost constant level in both communities for each collecting period. Flatidae and Membracidae appeared only in very small numbers throughout the study.

The remaining orders, with the exception of Coleoptera, were collected in extremely low numbers. Collections of coleopterans increased slightly in the woodlot during July and September with the appearance of numerous Curculionidae. In view of the fact that Coleoptera constitutes the largest insect order, its poor representation may be explained, in part, by their tendency to drop to the ground when they encounter an obstacle in flight (Matthews and Matthews, 1970, 1971).

Relative abundance of the insect orders in the woodlot and open field communities is represented on a weekly basis in Figs. 1 and 2. Most orders in the woodlot began to decrease numerically by September with the exception of Lepidoptera. All orders showed a population increase following rains which occurred during the third and fourth weeks of September.

In the open field community, several population trends were observed. Hymenoptera showed an increase in numbers during the second week of July, followed by a sharp decline. This order steadily decreased in population in the woodlot community. Lepidoptera also

Table 2. Percentage of major families of Diptera.

	May		July		September	
	Woodlot	Open Field	Woodlot	Open Field	Woodlot	Open Field
Bibionidae	1.55	*	*	*	*	*
Calliphoridae	4.96	6.01	1.95	1.50	*	*
Chironomidae	24.73	7.50	9.86	13.02	59.22	29.35
Culicidae	1.19	2.00	9.96	20.31	4.47	14.13
Dolichopodidae	*	3.71	4.47	5.54	*	2.38
Muscidae	3.05	9.44	11.20	8.39	3.04	5.43
Otitidae	*	1.14	*	*	*	*
Phoridae	1.61	3.58	13.32	3.39	*	1.50
Pipunculidae	*	1.00	*	*	*	*
Psychodidae	36.86	11.87	*	1.05	15.02	3.04
Rhagionidae	*	1.72	*	*	*	*
Syrphidae	1.76	8.30	*	1.05	*	1.08
Tabanidae	*	*	2.12	6.14	1.62	2.32
Tachinidae	6.66	19.60	31.51	27.84	10.08	24.35
Tipulidae	10.49	16.74	1.90	1.35	*	1.08
N	1936	699	1368	668	1052	460

* Values less than 1.00.

Table 3. Percentage of major families of Lepidoptera.

	May		July		September	
	Woodlot	Open Field	Woodlot	Open Field	Woodlot	Open Field
Hesperiidae	3.41	4.32	1.60	9.64	30.76	37.67
Lycaenidae	*	11.73	*	3.55	*	9.95
Noctuidae	9.76	7.41	6.07	4.57	3.51	1.90
Pyralidae	47.80	32.10	67.09	36.55	22.34	28.51
N	205	162	313	197	508	422

* Values less than 1.00.

Table 4. Percentage of major families of Hymenoptera.

	May		July		September	
	Woodlot	Open Field	Woodlot	Open Field	Woodlot	Open Field
Braconidae	5.77	3.08	1.67	*	*	*
Cynipidae	*	5.64	2.86	3.25	8.33	2.09
Eucoilidae	*	1.54	19.09	3.25	5.73	12.00
Formicidae	8.89	24.62	*	19.80	29.17	2.09
Halictidae	4.81	7.18	21.48	29.27	3.65	26.96
Ichneumonidae	72.36	47.18	17.42	21.95	29.17	25.71
Scoliidae	*	1.03	10.91	6.91	10.42	12.57
Sphecidae	1.68	1.54	7.16	6.91	3.13	1.14
Tiphiidae	*	*	2.86	1.22	1.04	6.86
Vespidae	3.81	6.13	3.34	4.47	5.73	8.29
N	416	195	419	246	192	175

* Values less than 1.00.

Table 5. Percentage of major families of Homoptera.

	May		July		September	
	Woodlot	Open Field	Woodlot	Open Field	Woodlot	Open Field
Aphididae	10.69	*	3.13	1.69	*	*
Cicadellidae	88.05	95.31	95.31	94.94	99.01	95.96
N	159	171	128	118	127	124

* Values less than 1.00.

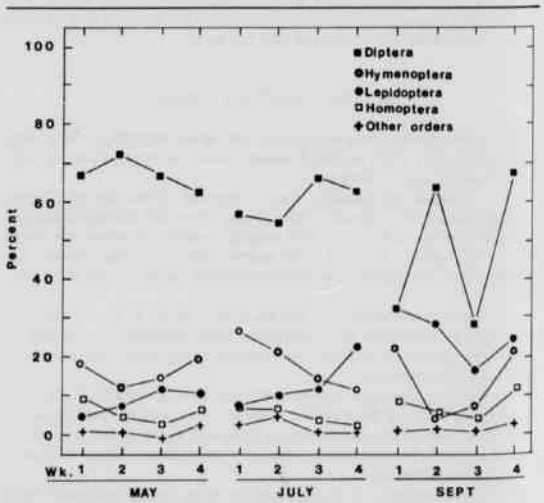

Fig. 1. Relative abundance of insect orders in woodlot.

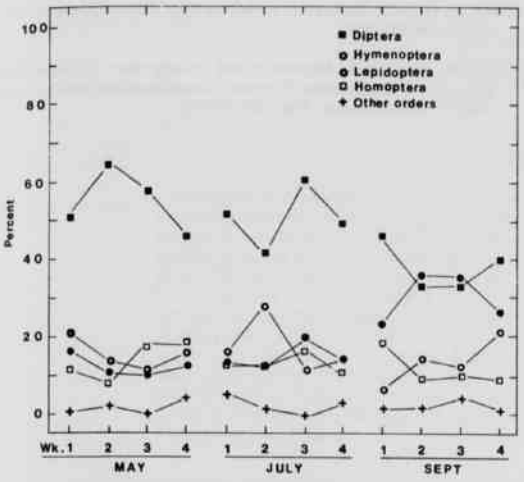

Fig. 2. Relative abundance of insect orders in open field.

increased in numbers during mid-summer in the open field but not in the woodlot. All orders except Diptera and Hymenoptera declined in population rather than increasing as in the woodlot after the rains in late September.

Table 6. Summary of all taxa collected.

Diptera	Hemiptera	Lepidoptera
Anthomyidae	Berytidae	Arctiidae
Asilidae	Lygaeidae	Ctenuchidae
Bibionidae	Miridae	Hesperiidae
Bombylidae	Pentatomidae	Lycaenidae
Calliphoridae	Reduviidae	Noctuidae
Cecidomyiidae	Neuroptera	Notodontidae
Chironomidae	Chrysopidae	Nymphalidae
Culicidae	Hemerobiidae	Papilionidae
Dolichopodidae	Coleoptera	Pieridae
Muscidae	Buprestidae	Pyralidae
Mycetophilidae	Carabidae	Sphingidae
Otitidae	Cerambycidae	Microlepidoptera
Pipunculidae	Chrysomelidae	Hymenoptera
Phoridae	Coccinellidae	Andrenidae
Psychodidae	Curculionidae	Apidae
Rhagionidae	Elateridae	Braconidae
Sarcophagidae	Lampyridae	Chrysididae
Stratiomyidae	Melandryidae	Cynipidae
Syrphidae	Mordellidae	Evaniidae
Tabanidae	Scarabaeidae	Formicidae
Tachinidae	Odonata	Halictidae
Tephritidae	Coenagrionidae	Ichneumonidae
Therevidae	Orthoptera	Megachilidae
Tipulidae	Acrididae	Pompilidae
Homoptera	Blattidae	Scoliidae
Aphididae	Mantidae	Sphecidae
Cicadellidae	Tetrigidae	Tiphiidae
Flatidae	Tettigoniidae	Vespidae
Membracidae		

Table 7. Total seasonal composition by insect order.

	May			July			September		
	Woodlot	Open field	%Total	Woodlot	Open field	%Total	Woodlot	Open field	%Total
Diptera	1036	699	55.37	1366	665	55.99	1052	460	47.76
Lepidoptera	205	162	9.19	313	197	14.04	308	422	29.37
Hymenoptera	424	185	17.16	429	296	18.92	190	171	11.79
Homoptera	159	171	9.19	185	139	8.40	127	124	7.93
Coleoptera	32	31	1.66	77	41	3.33	66	16	2.56
Neuroptera	11	4	0.37	3	3	0.17	1	4	0.16
Orthoptera	2	1	0.07	3	7	0.28	0	3	0.14
Hemiptera	0	2	0.05	1	2	0.08	5	3	0.25
Odonata	1	0	0.02	1	0	0.03	0	4	0.14
n	2769	1269	4038	2711	1390	4101	1951	1215	3166

CONCLUSIONS

A summary of all taxa in the nine orders collected is represented in Table 6. The seasonal composition by insect order (Table 7) can be summarized by the following:

The woodlot turned out to be the prominent collecting site for this study, responsible for approximately 65% of the total catch each month. The open field community was most productive during the July collection period. Insect abundance was greatest during May, declining as the season progressed with the lowest numbers being collected in September.

The decrease of insect numbers collected from mid- to late-season may be related to extreme weather conditions (Table 1). This study was conducted during the longest hot-and-dry period ever recorded for this area.

The ordinal composition of this study compares favorably with similar Malaise trap studies of Matthews and Matthews (1970, 1971) and Martson (1965). They found that orders Diptera, Hymenoptera, Lepidoptera and Homoptera comprised at least 90% of the total collection (Matthews and Matthews, 1971). They also found that Hymenoptera generally occupied the second ordinal position. However, in this study, Lepidoptera represented the second largest order, exceeding Hymenoptera by 2%.

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SEASONAL ABUNDANCE, MOVEMENT AND DIVERSITY OF FISHES IN AN OZARK STREAM

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ABSTRACT

Seasonal fluctuations in fish abundance in Mud Creek occurred throughout the year at all sampling stations. At the two upper stations abundance was high and unstable during winter and early spring and decreased after heavy rainfall in mid-April. Abundance was low throughout the summer months, increasing in the fall due to large numbers of young-of-the-year. However, a different seasonal cycle occurred at the lower station which included deeper pools. Numbers were low and stable throughout the winter and early spring but high and unstable during the summer. Bigeye shiners (*Notropis boops*) and bluntnose minnows (*Pimephales notatus*) were the most mobile species marked. Populations of brook silversides (*Labidesthes sicculus*) remained fairly isolated, stable, and showed little mobility. Mean species diversity fluctuated during the winter, spring, and fall; diversity values were highest and most stable during summer months when high and relatively stable numbers were collected. The main difference in mean species diversity between stations was the greater stability throughout the year at the upper station.

INTRODUCTION

Little is known about the variability of movement among the various species of small fishes in streams. The movement of game fishes, especially the salmonids and centrarchids, has been studied extensively in streams with variable results. Thompson (1933), Stefenich (1951), Bjornn and Mallet (1964), Brown (1961), Behmer (1964), Hunt (1964), and Shetter (1968) found extensive movement by game fishes in streams. Bangham and Bennington (1938), Scott (1949), Tate (1949), Gerking (1950, 1953) and Gunning and Shoop (1963) concluded that there was relatively little movement of the fishes studies. Gerking (1959) discussed the restricted movement of fishes. Funk (1955) offered an explanation for the variability of movement among fishes by stating that there are "sedentary" and "mobile" segments within fish species, with the percentage of each segment varying according to species.

Some studies have dealt with the movement of small fishes in streams; however, most of these studies did not include a comparison of seasonal movement. The movement of small fishes has been shown when decimated areas were repopulated. These reported rates of repopulation have varied (Harrel et al., 1967; Gunning and Berra, 1969; Cairns et al., 1971; Olmsted and Cloutman, 1974). Wickliff (1941) found wide fluctuations in numbers of darters, minnows, and suckers in the riffle area of an Ohio stream with maximum periods of abundance occurring during the summer and fall. Lairmore (1954) reported that minnow populations followed cycles of abundance in an Illinois stream, with numbers low in the winter and spring but high in the summer due to the addition of young-of-the-year. Winn (1958) found some movement between pool and riffle areas by darters in Michigan streams. Reed (1968) studied the darters of Pennsylvania streams during the summer months and found that darters stayed in a riffle area or in an adjoining pool. Paloumpis (1958) studied an unstable Iowa stream and concluded that fish population changes were rather small considering the unstable habitat. Smith (1963) reported that numbers of fishes decreased sharply during the spring and early fall and increased during the summer and winter in an Illinois stream. The breaking up of winter aggregations, the increased alterness and activity of fishes as the water warmed, the establishment of breeding territories winter kills, and the diluting effects of spring rains were suggested as reasons for the low numbers in the spring and early summer. Movement of fishes in two North Carolina streams was shown by Hall (1972) and was found to be less during low water periods in late summer and winter. The movement of the largest number of fishes occurred from April until June. Hubbs and Wauer (1973) reported that seasonal changes of abundance varied among several species of minnows in a west Texas stream.

Changes in abundance, mark-recapture data, and diversity indices were used in this study to gain some understanding about the movement and population stability of stream fishes. The objectives of this study were to (1) study the seasonal movement or stability of fishes in Mud Creek, an Ozark stream, (2) compare the mobility of the bigeye shiner (*Notropis boops*), the bluntnose minnow (*Pimephales notatus*), the blackspotted topminnow (*Fundulus olivaceus*), the brook silverside (*Labidesthes sicculus*), and the orangethroat darter (*Etheostoma spectabile*), and (3) determine the seasonal changes in diversity of a stream fish community.

Mud Creek, a tributary of Clear Creek, in the Illinois River system, is located in north-central Washington County, Arkansas. It is approximately 9 km long and flows in a northwest direction (Fig. 1). The drainage area consists of pastureland and residential areas. Compared with many Ozark upland streams, Mud Creek has a relatively low gradient and muddy substrate.

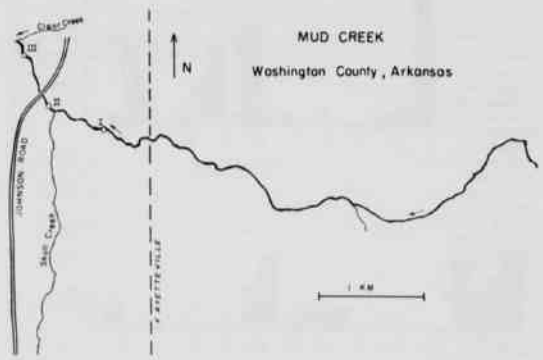

Figure 1. Sampling stations on Mud Creek, Washington County, Arkansas.

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METHODS AND MATERIALS

Three sampling stations, designated I, II, and III, were established in December 1971. Station I, the uppermost station, was approximately 1.5 km from the mouth of the stream. Stations II and III were located at progressive 0.5 km intervals downstream from Station I. In the area sampled, the average stream width and depth were 5.0 and 1.0 m, respectively. Each station was divided into three contiguous substations: A, B, and C. Substation A was uppermost at each station. Substations A and C were sections of pool areas connected by a riffle or riffle-raceway area which was designated Substation B.

Collections were made twice each month from December 1971, through November 1972. Sampling at Substation III-B was discontinued after the first collection in July because the riffle was covered by gravel after heavy rains. Sampling at Station II had to be discontinued after the first collection in September when much of the bank area was cleared of vegetation during the second and third weeks of September with trees and soil being pushed into the water.

A minnow seine, 6.1 m long with 6.4 mm mesh, was used to sample each station. Collections were made at Substations A and C by making one seine haul the length of the substation. At Substation B of each station, the seine was held at the lower end of the riffle, while one person, beginning at the upper end and moving toward the seine, kicked the riffle and displaced the gravel.

After each substation collection, the captured fish were identified and counted. The five species of fishes fin-clipped to study their movements were the bigeye shiner, the bluntnose minnow, the blackspotted topminnow, the brook silverside, and the orangethroat darter. If any of these species were captured in large numbers at a substation, usually 20 to 30 fish were fin-clipped and the rest released unmarked. A different combination of fin marks were used at each substation. Only two fins were used in each combination, and only half of the caudal fin was removed from any fish. Small fish of many species (usually less than 25-30 mm in length) which first appeared in the collections during late May, were classified as young-of-the-year (YOY).

The diversity index used in this study (mean diversity per individual), (Wilhm and Dorris, 1968), is expressed as follows:

$$\bar{d} = \sum_{i=1}^{s} \left(\frac{n_i}{n}\right) \log_2 \left(\frac{n_i}{n}\right)$$

Where n is the total number of individuals, n_i is the number of individuals of species i, and s is the number of species per unit area. Mean diversity indices derived from information theory are independent of sample size. Also, when d is used, the contribution to total diversity by rare species is small (Wilhm and Dorris, 1968).

RESULTS AND DISCUSSION

Seasonal Abundance and Stability.

December through February (Winter): Twenty-one species representing eight families were collected during the study (Table 1). Throughout the winter, large fluctuations in abundance were found between and within months at Stations I and II (Fig. 2). The winter abundance levels were relatively high at both stations compared to the entire study period. The fluctuations were smaller at Substation I-C because of a population of brook silversides that remained fairly stable throughout the winter. Distinct differences were shown between the two pool substations at Station II during the winter. Substation II-A showed relatively low, stable abundance levels because of stable numbers of orangethroat darters. However, at Substation II-C, where a wider variety of species was collected, large fluctuations in abundance occurred mainly because of changes in abundance of bigeye shiners. The riffle substation, where the fish population consisted mainly of orangethroat darters and stonerollers (*Campostoma anomalum*), also showed great stability in numbers. At Station III, the fish population remained relatively constant. During the winter months the abundance of fishes showed greatest stability in the deeper waters of Station III, possibly indicating less movement in the deeper waters than in the shallower pool areas at the other two stations.

March through May (Spring): Large changes in abundance were found at all three stations (Fig. 2). High abundance levels in March and early April at Stations I and II were due to increasing numbers of bigeye shiners and bluntnose minnows. The numbers of fishes collected at Stations I and II decreased from the second collection in April through May. Rainfall totaling over 8 cm caused high water during the second week of April. After this period, the numbers of fishes collected increased at Station III, the lowermost station. Gerking (1950) reported that high waters had very little effect on the stability of a stream population consisting mainly of centrarchids. However, in Mud Creek the heavy runoff caused by excessive rainfall was followed by definite reductions in the fish populations at the two upper stations and a definite increase of fishes at the lowermost station through May, indicating a downstream movement of fishes.

Changes in abundance throughout the spring were caused mainly by fluctuating and increasing numbers of bigeye shiners, bluegills (*Lepomis macrochirus*) and longear sunfishes (*L. megalotis*). Fish

Table 1. Seasonal occurrence of fishes collected in Mud Creek (Roman numerals are station numbers).

Fishes collected	Dec.			Jan.			Feb.			Mar.			Apr.			May		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Notemigonus crysoleucas	•		•	•			•			•	•		•					
Notropis hoops	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•
N. chrysocephalus																		
N. umbratilis																		
Pimephales notatus	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•
Dionda nubila			•							•			•					
Semotilus atromaculatus										•								
Hoyumis argyr																•	•	
Campostoma anomalum		•	•		•	•		•			•			•		•		
Ictalurus melas													•					
Moxostoma erythrurum																		
Fundulus olivaceus	•			•				•	•		•			•	•			
Gambusia affinis						•						•						
Labidesthes sicculus	•			•	•					•	•	•						
Micropterus salmoides	•						•				•		•			•		
Lepomis macrochirus	•	•	•				•	•	•	•	•	•	•	•		•		•
L. cyanellus		•	•	•		•	•	•	•	•	•						•	•
L. megalotis			•			•	•	•	•	•			•	•	•			
L. microlophus										•								
Etheostoma spectabile	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
E. flabellare		•				•			•									

* denotes the collection of fishes

Fishes collected	June			July			Aug.			Sept.			Oct.			Nov.		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Notemigonus crysoleucas							•						•			•		
Notropis hoops	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	
N. chrysocephalus		•			•			•					•			•		
N. umbratilis		•																
Pimephales notatus	•	•		•	•	•	•	•		•	•		•	•				
Dionda nubila				•														
Semotilus atromaculatus																		
Hoyumis argyr	•	•			•													
Campostoma anomalum	•	•		•	•	•	•											
Ictalurus melas				•			•											
Moxostoma erythrurum								•										
Fundulus olivaceus	•	•	•	•	•	•	•	•	•	•	•	•	•	•				
Gambusia affinis					•		•	•		•	•	•	•	•				
Labidesthes sicculus	•	•	•	•	•	•	•	•		•	•	•	•	•				
Micropterus salmoides	•	•	•		•	•												
Lepomis macrochirus	•	•	•	•	•	•	•	•	•	•	•	•	•	•				
L. cyanellus	•			•		•	•						•			•		
L. megalotis	•	•		•	•	•	•	•	•	•	•	•	•	•		•		
L. microlophus				•														
Etheostoma spectabile	•	•		•	•		•			•	•		•	•		•		

* denotes the collection of the fishes

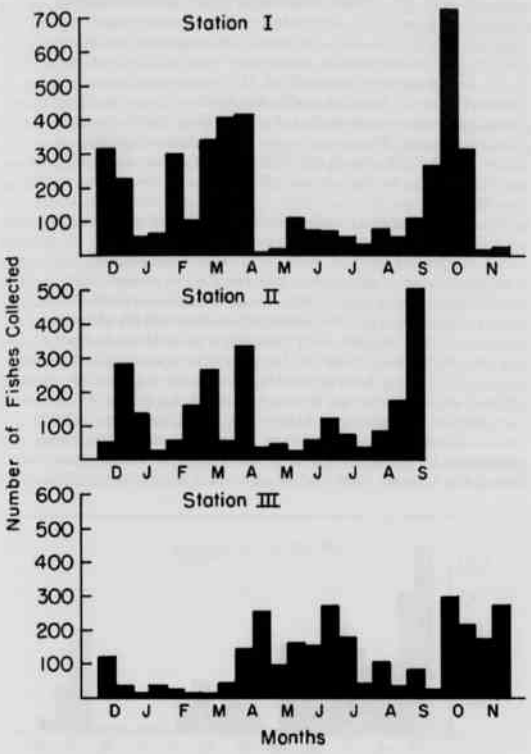

Figure 2. Seasonal occurrence of fishes at three sampling stations.

populations at riffle substations remained relatively stable throughout the spring, while fish populations in the pools fluctuated at all stations.

June through August (Summer): Abundance levels were comparatively low and stable at Station I and II (Fig. 2). The increase in fishes at Station II during the last collection in June was due to an aggregation of YOY brook silversides. High abundance levels at Station III during June and July were due to the presence of YOY of 12 species, mostly cyprinids. The number of fishes at all stations declined during late July, possibly due to rainfall of over 12 cm during a two-day period in mid-July. During the summer months, numbers were low in the warm, shallower pools at Stations I and II, while numbers in the deeper pools at Station III increased.

Populations at riffle substations remained relatively stable throughout the summer. Fluctuations in abundance at the pool substations were caused mainly by fluctuating populations of YOY cyprinids, centrarchids, and atherinids.

September through November (Fall): Abundance of YOY fishes peaked in September and October at all stations, and increasing numbers of fishes were collected at all stations (Fig. 2). This increase was due to the abundance of bigeye shiners, bluntnose minnows, and bluegills. The extent of the spawning periods of these species in Mud Creek is unknown. Paloumpis (1958) found that bluntnose minnows spawned throughout the summer in an Iowa stream. Throughout the fall, at all stations in Mud Creek, the numbers of YOY fluctuated, indicating the mobility of the young fishes.

Table 2. Mark and recapture data of five fin-clipped species in Mud Creek, Washington County, Arkansas.

	Species				
	Bigeye Shiner	Bluntnose Minnow	Brook Silverside	Blackspotted Topminnow	Orangethroat Darter
Number of fish marked	1,188	529	494	120	263
Percentage of marked fish recaptured	11.9	6.5	36.0	10.0	3.8
Percentage of recaptured fish caught at same station where marked	84	83	98	83	100
Percentage of recaptured fish caught at same substation where marked	39	48	97	75	90

It is difficult to make generalizations concerning this stream-fish community, since variations between stations were noted throughout the year. Changes in numbers of fishes collected indicated dynamically fluctuating populations in Mud Creek throughout the year.

Mobility of Some Selected Stream Fishes.

A paucity of work exists concerning the differences in mobility among the smaller streams. Funk (1955) reported that fish species consist of "mobile" and "sedentary" segments, but he studied only the movements of game fishes. In Mud Creek, mobility was analyzed by

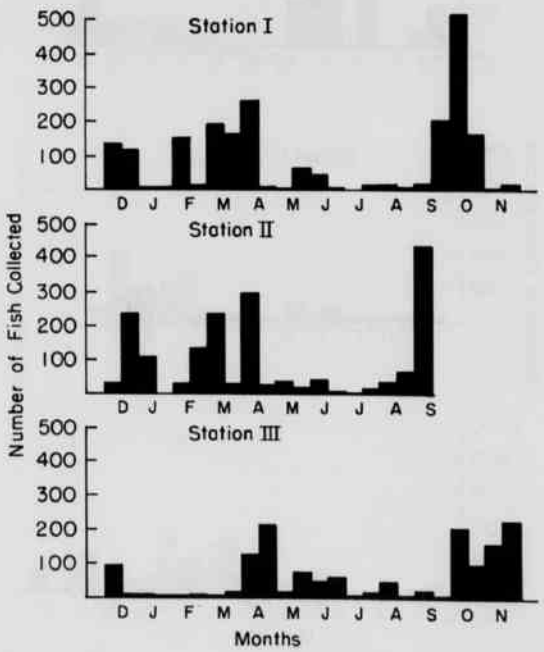

Figure 3. Seasonal abundance of the bigeye shiner.

using both changes in abundance and mark and recapture data. The division of each station into three substations allows for a more intensive study of the localized movements at each station. The percentage of recaptures collected at the same station where they were marked was relatively high for all species, probably because of the limited area sampled outside each station. Recaptured fish were returned to the stream population. Therefore, it was possible to capture a marked fish more than once. This could inflate the recapture percentages to some extent.

Bigeye shiners were the most common of the species marked. Abundance fluctuated greatly throughout the study (Fig. 3). Fluctuations were smallest during the summer months. Of 1,188 bigeye shiners fin-clipped, 11.9% were recaptured, and 84% of those were recaptured at the same station where they were marked (Table 2). This species had the lowest percentage of recaptured at the substation where they were marked, indicating greater mobility within the stations, compared with the other species. Of the fish recaptured at a different station than where they were marked, 68% had moved upstream, while 32% had moved downstream. Although the numbers of fish used in calculating these percentages were low, this did indicate a tendency to move upstream. Smith and Powell (1971) found little migration by this species between pools during low-water periods.

Fluctuations in abundance of bluntnose minnows occurred throughout the year (Fig. 4). Generally, bluntnose minnows seemed more abundant during spring and fall in Mud Creek. However, seasonal abundance varied noticeably from station to station, so it is difficult to generalize concerning cycles of abundance. Of 529 fish marked, only 6.5% were recaptured. Of those, the percentage of fish collected at the substation where they were marked was 48%, relatively low compared with all of the other species except bigeye shiners (Table 2). One fish marked at Station II was accidentally collected in another study during April in Clear Creek approximately 5 km downstream. These data seem to indicate a high degree of mobility. Smith (1963) found that bluntnose minnows showed the greatest fluctuations in abundance of all fishes collected in an Illinois stream.

Fluctuations of abundance based on mark and recapture data indicate that brook silversides are relatively sedentary (Fig. 5). Of 4949 brook silversides marked, 36% were recaptured—the highest recapture percentage of all marked species. Of the recaptured fish, 98% were collected at the same station where they were marked, and 97% were recaptured at the same substation. Populations of brook silversides seemed to remain fairly isolated with little exchange between populations in different areas. Large numbers were collected at Substation I-C during the winter, while few were collected at all other substations. Population levels remained high and fairly stable through the spring only at Substation I-C. These data indicate that brook silverside populations may congregate in certain areas, with population levels remaining fairly stable. Numbers of adults collected during the summer were low. High natural mortality of adults could

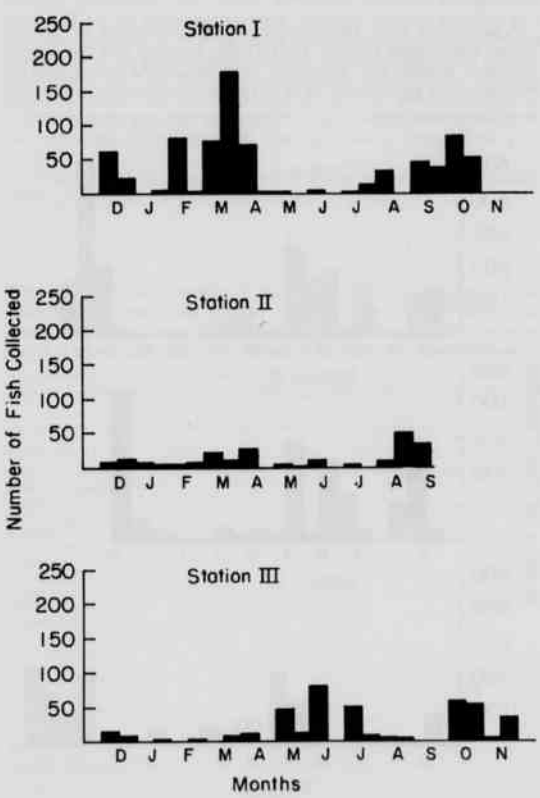

Figure 4. Seasonal abundance of the bluntnose minnow.

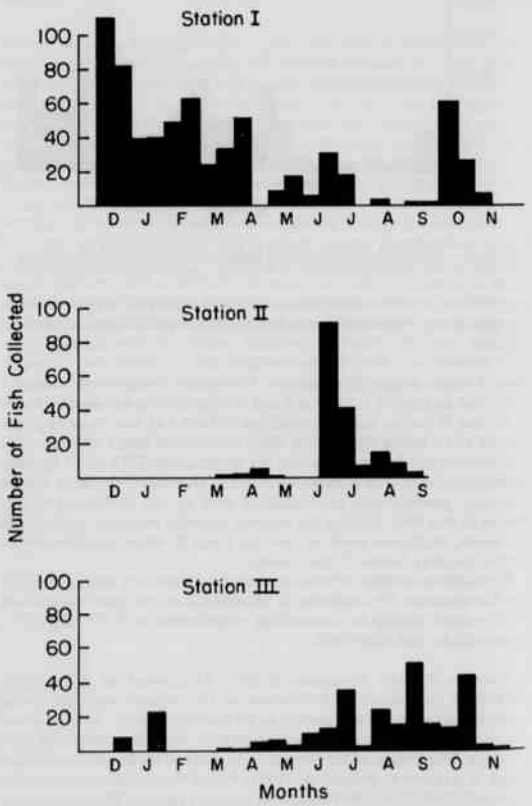

Figure 5. Seasonal abundance of the brook silverside.

have occurred. Hubbs (1921) stated that brook silversides probably die before the second winter of life. Nelson (1968) found no second annuli on scales from brook silversides collected at Crooked Lake, Indiana. However, Fogle (1959) found second annuli on scales from a few male silversides collected at Lake Fort Smith, Arkansas.

Blackspotted topminnows, although not present in large numbers, showed seasonal fluctuations (Fig. 6). They were first collected in relatively large numbers in the spring at the lowermost station, which might indicate movement from Clear Creek into Mud Creek. Numbers fluctuated at all stations during the summer. Young-of-the-year were collected from June through October with all the YOY collected at the lowermost station. The YOY may have moved out of Mud Creek into Clear Creek during late summer or early fall, causing a decline at all stations.

Small fluctuations in abundance of orangethroat darters in Mud Creek indicated population stability. Numbers were highest in the winter months. Of the numbers collected, 76% were from pools, and 24% were from riffles (Fig. 7). During the spring, numbers remained high only at Station III which included the largest riffle of all the stations. After March, less than 10 orangethroat darters were found at Station I, possibly because they had left the pool to spawn in riffles and didn't return. Station II had a relatively stable population during summer. Numbers were high and stable at Station III until late July when heavy rainfall destructed the riffle substation. For three months afterwards, none of this species was collected in the pool substations of Station III. Winn (1958) reported that orangethroat darters remained in calm raceway areas or in pools during the non-breeding season. Gerking (1959) stated that orangethroat darters are restricted in their movements. Reed (1968) studied six species of darters from Pennsylvania streams and found that relatively few moved from one riffle to another.

Of 263 orangethroat darters marked, only 3.6% were recaptured (Table 2), for several reasons. The destruction at the lower station destroyed the largest riffle sampled. Also, fin regeneration could have influenced the recognition of recaptures. Reed (1968) began marking darters in June, and by late summer many recaptures possessed a temporary white-tipped fin which eventually became normally colored. The efficiency of collecting darters, especially in the deep or rocky pool areas, was relatively low because many darters probably escaped under the lead line of the seine. The mark and recapture data were not enough to determine the extent of mobility of this species. However, the stability of numbers at the lower station seems to indicate that population levels of orangethroat darters remained relatively stable.

Differences in both fluctuations in abundance and recapture rate were noted for the five species studied. The mark and recapture data for bigeye shiner, bluntnose minnow, and brook silverside were the most significant, since the number of fish marked was considerably higher for those species. Bigeye shiners and bluntnose minnows seemed to be the most mobile of the marked species.

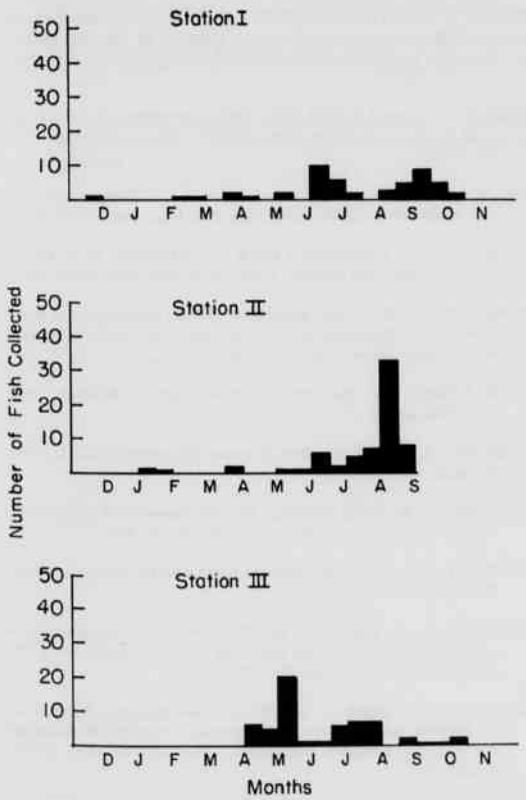

Figure 6. Seasonal abundance of the blackspotted topminnow.

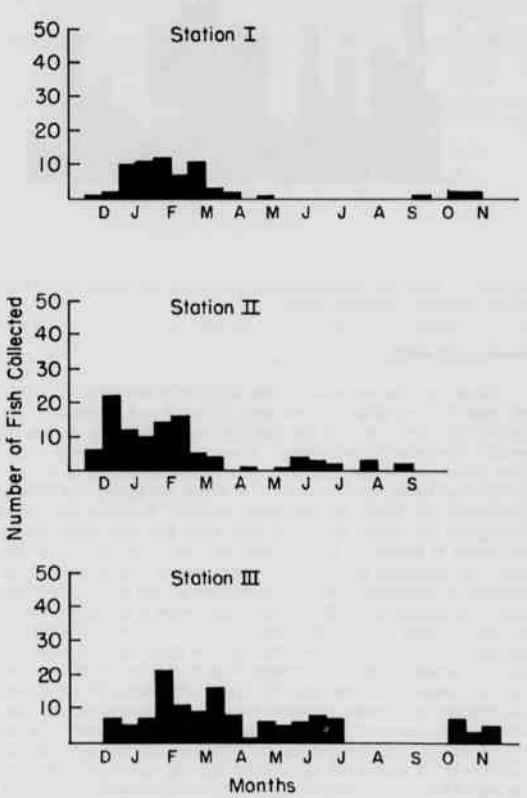

Figure 7. Seasonal abundance of the orangethroat darter.

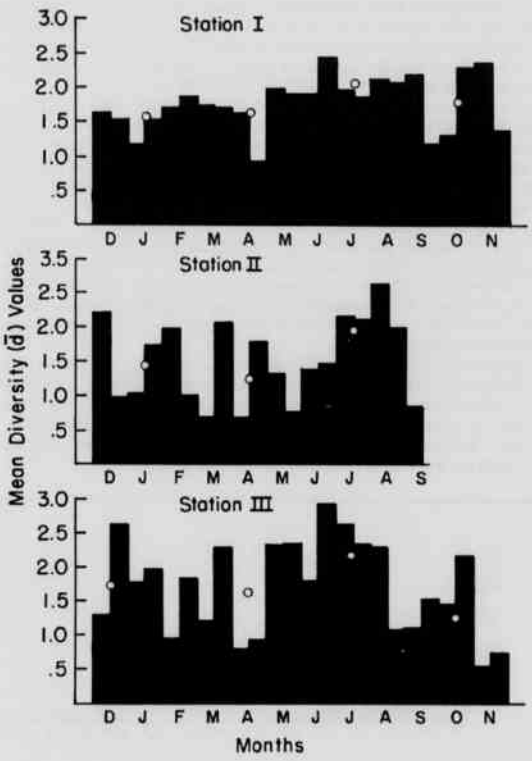

Figure 8. Seasonal changes in mean diversity (d). Open circles represent seasonal average d values.

Seasonal Diversity.

Community structure refers to the complex of individuals of different species comprising a community (Prather and Prophet, 1969). Community structure can be quantitatively defined by the use of species diversity indices. Mean diversity (d) values were stable throughout the winter months at the upper station (Fig. 8); one reason may be the stable numbers of brook silversides collected at Substation I-C then. At the other stations, d values fluctuated throughout the winter. Mean diversity values also were stable during the spring at Station I. The extreme low value for Station I in late April was probably the result of heavy rainfall which affected the community structure. However, at Stations II and III, d values also fluctuated greatly during the spring, with Station II having the lowest average d value during that time. The number and diversity of centrarchids collected at the other stations probably accounted for this fluctuation. From June through August, d values were high and relatively stable at all stations. The highest d values and the highest seasonal average d value occurred during the summer at each station. Smith (1963) reported that the richest species representation in an Illinois stream community occurred in late spring and early fall. In Mud Creek, d fluctuated throughout the fall. At Station III, the seasonal d value was noticeably lower, due to the absence of the riffle substation. Another factor responsible for these fall fluctuations in mean diversity was the changing numbers of YOY collected.

The seasonal patterns of mean diversity were generally similar at all stations, with the exception of the seasonal stability of d at the upper station. However, fluctuations in mean diversity occurred throughout the year, indicating dynamic stream-fish communities.

ACKNOWLEDGMENTS

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THE AQUACULTURE INDUSTRY OF ARKANSAS IN 1979-1980

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ABSTRACT

A survey of previous fish farmer certificate holders in Arkansas was conducted during 1979-1980 using renewal questionnaires, telephone conversations, and personal contacts. This survey was compared with similar surveys from preceding years. Approximately 51.0% of 12,372 intensively farmed hectares in 1979-80 were devoted to bait fish production, while 22.9% were utilized in food fish production. Acreage in bait fish, food fish, and fingerling production decreased from 1979 to 1980; however, price increases during this time resulted in a higher total value of the industry.

INTRODUCTION

In 1968, Meyer et al. conducted one of the first surveys on the commercial production of fishes in Arkansas. Since then, the fish farming industry has shifted from a "new industry" type growth (Meyer et al., 1971 and Bailey et al., 1974) and currently fluctuates according to supply and demand (Bailey et al., 1978). Changes in the industry have been monitored periodically during the last 13 years as part of the Commercial Fisheries Industry Survey, partially funded as a Public Law 88-309 Project by the National Marine Fisheries Service.

Since Arkansas is located in the middle of the fish belt (Hulsey, 1965), changes in fish production values for the state should reflect national trends in the warm water production of fish. The current survey documents the changes in the industry from 1 July 1976 to 30 June 1980.

METHODS AND MATERIALS

Each year the Arkansas Game and Fish Commissions's Fiscal Division contacts previous fish farmer certificate holders by means of a renewal notice. In 1977, these notices also inquired about the production acreage of various fish species. Although answering the questions was not mandatory for certificate renewal, most applicants cooperated, listing the acreage of each fish species they planned to grow in 1979. A telephone survey was conducted during the summer of 1980 to verify the farmers' acreage estimates and to obtain further information on yields per acre and current market prices. When the farmer could not be contacted by phone, his 1979 projection was deemed valid and was used in calculating the total acreages in production.

An effort was made during this telephone survey to contact any applicant who had not responded to the renewal notice questions. When this attempt failed, the applicants were visited, when possible, by their district fisheries biologist. Fish farmers not contacted at all were not included in the survey. All values were obtained in English units, tabulated, and then converted to metric units. Yields per hectare and prices per kilogram represent weighted means calculated for those fish farmers reporting. Tables 2, 3, and 4 were modified after Henderson et al. (1978), Henderson and Wooldridge (1977) and Bailey et al. (1978), respectively.

RESULTS AND DISCUSSION

During 1979, 376 fish farms were licensed, 19 fewer farms than in 1978. Bait fishes were raised by 119 of the surveyed farmers, food fishes by 270 farmers, and fingerlings, ornamental exotics, and miscellaneous fishes by 50 farmers. Acreage and production values supplied by applicants are believed to be reasonably accurate by the authors.

Bait fish production accounts for 51.0% of the intensively farmed water in Arkansas (Table 1). Total area in bait fish production has been down since 1976-77 (Tables 3 and 4), except for an unusually large increase in 1977-78 (Table 3). The principle species raised for bait in order of importance continue to be the golden shiner *(Notemigonus crysoleucas)*, fathead minnow *(Pimephales promelas)*, and goldfish *(Carassius auratus)*. Production of Israeli carp *(Cyprinus carpio)*, the nearly scaleless variety of the common carp, was no longer intensively farmed for bait fish or vegetative control and was left out of the 1979-80 (Table 1) report.

Prices for the three major species of bait fishes have increased since 1976-77 as a result of inflationary pressures. The value of the bait fish industry has increased by 20.3% since 1976-77. The price

Table 1. Commercial fish production in Arkansas — 1 July 1979 to 30 June 1980.

	Hectare	Kg./ Hectare	Total Kg.	Price/ Kg.	Total Value
Bait Fishes					
Golden Shiner	6,672	426	2,832,744	$4.29	$12,151,919
Fathead Minnows	696	449	402,505	4.42	1,859,761
Goldfish	639	898	394,596	5.50	2,170,560
Total	7,955		3,629,809		$16,183,679
Food Fishes					
Catfishes	2,439	2,555	6,231,843	$1.43	$ 8,912,570
Buffalofish	264	1,123	409,260	.66	270,069
Buffalo (Polyculture with catfish)	167	381	222,726	1.19	264,600
Trout	8	6,835	45,450	4.95	225,000
Cage Reared Trout	---	---	6,585	5.30	35,068
Cage Reared Catfish	---	---	44,565	1.43	63,738
Tank and Raceway Trout	---	---	45,450	4.40	200,000
Extensive Farming[1]					
All Species	2,922	1,356	4,670,237	1.32	6,168,240
Pay Fishing (Intensive)					
Channel Catfish	196	602	117,908	1.43	168,671
Pay Fishing (Intensive)					
Trout	4	13,476	60,086	4.40	264,380
Pay Fishing (Non-Intensive)[1]					
All Species	800	---	---	---	2,600
Total Food Fish	6,802		11,847,829		$16,114,133
Ornamental Exotics	57	1,615	91,445	$8.80	843,000
Fingerlings and Miscellaneous					
Largemouth Bass	1	4,884[2]	12,200[3]	$1.38[4]	$ 17,000
Catfish (Fingerlings)	696	2,021	1,406,314	2.75	3,867,750
White Amur	83	674	49,086	6.60	324,000
Crayfish (Bait)	17	20,590[2]	245,990[3]	.03[4]	7,500
Total	782		1,455,400		$ 4,211,250
			281,990 Fish		
GRAND TOTAL	19,196		17,023,483 kg.		$37,743,744
			281,990 Fish		

1/ These totals should not be included when comparing intensive culture of 1980 to that of previous years.
2/ Fish/ha.
3/ Fish
4/ Price/Fish

used for goldfish was an average of the weighted means for feeder (aquaria) goldfish and trotline-sized goldfish, assuming an equal production ratio.

Food fishes were produced on 22.9% of the intensively farmed water in Arkansas (Table 1). Fish production was the primary concern for intensively farmed waters whereas it was of secondary importance in extensively farmed waters. Examples of the latter included private lakes, some free fishing lakes and irrigation reservoirs licensed as fish farms for various reasons and often only partially harvested. Food fishes were raised intensively and extensively on 43.6% of the total area devoted to fish farming in 1979-80. A wide species variety was present in extensively farmed ponds. Intensively farmed food fish species included the channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*), bigmouth buffalo (*Ictiobus cyprinellus*) and rainbow trout (*Salmo gairdneri*).

Intensive production of food fish has remained stable since 1976. The data collected (for 1980) agreed with data recorded in the U. S. Department of Agriculture's 1980 Aquaculture report.

Private cage culture operations that appeared so promising in 1975-76 (Bailey et al., 1978) have apparently suffered from mismanagement, financial problems and environmental conditions. While the weight of cage-produced trout has remained relatively stable since 1976-77 (Table 2, 3, & 4), it decreased 82% for 1979-80 (Table 1). The weight of cage-produced channel catfish decreased by 57.1% during 1978-79 and again during 1979-80 for a total of 67.2% from 1976-78 (Table 3 & 4).

Ornamental fish production increased 35.7% because one farmer switched from bait fish ponds to ornamentals. Catfish fingerling production varies from year to year as the farmers evaluate both their demands and the economic needs of future markets. Production for 1979-80 decreased 13.3%. Therefore, a possible decrease in food catfish may occur next year.

The production of white amur as a weed control agent rose when Missouri lifted its import ban. Increased production area offset a decrease in price per kilogram causing an overall increase in total crop

Table 2. Commercial fish production in Arkansas — 1 July 1978 to 30 June 1979.

	Hectare	Kg./ Hectare	Total Kg.	Price/ Kg.	Total Value
Bait Fishes					
Golden Shiner	7,340	357	2,623,380	$3.81	$ 9,991,593
Fathead Minnows	1,033	449	463,914	3.85	1,786,408
Goldfish	448	736	329,642	4.05	1,631,894
Israeli Carp	12	337	4,277	2.20	9,409
Totals	8,840		3,421,205		$13,413,185
Food Fishes					
Catfish	2,615	2,555	6,680,593	$1.43	$ 9,554,204
Buffalo	372	1,179	438,570	.59	260,537
Buffalo (Polyculture with Catfish)	697	410	244,691	1.18	290,723
Trout	8	5,989	46,480	4.40	205,732
Cage Trout	---	---	36,360	2.97	108,060
Cage Catfish	---	---	126,575	1.43	181,025
Raceway Trout	---	---	45,450	4.09	186,000
Extensive Farming[1]					
All Species	2,715	1,598	4,342,950	$1.32	5,733,287
Fee Fishing (Intensive)					
Channel Catfish	237	602	124,729	1.43	178,386
Fee Fishing (Intensive)					
Trout	4	13,364	48,877	$3.85	$ 187,425
Fee Fishing (Non-Intensive)[1]					
All Species	582	---	---	---	5,925
Totals	7,103		12,137,370		$16,883,793
Ornamentals	36	1,604	61,345	$2.85	$ 542,000
Fingerlings and Miscellaneous					
Largemouth Bass	1	6,884[2]	17,000[3]	1.00[4]	$ 17,000
Catfish	803	2,138	1,716,840	2.68	4,576,018
White Amur	20	674	13,029	7.70	147,060
White Amur and Silver Carp	16	1,123	16,180	6.60	110,400
Trout Fingerlings	---	---	1,364	6.60	9,000
Crayfish	12	20,580[2]	240,960[3]	.03[4]	7,560
Freshwater Shrimp	1	880	727	11.00	8,000
Totals	861		1,746,250 + 261,880 fish		$ 4,874,918
Grand Totals	16,840		17,375,881 kg. + 261,880 fish		$31,711,396

1/ These totals should not be included when comparing intensive culture of 1979-1979 to that of previous years.
2/ Fish/ha.
3/ Fish
4/ Price/fish

Table 3. Commercial fish production in Arkansas — 1 July 1977 to 30 June 1978.

	Hectare	Kg./ Hectare	Total Kg.	Price/ Kg.	Total Value
Bait Fishes					
Golden Shiners	3,469	331	3,770,784	$2.41	$12,966,906
Fathead Minnows	845	466	394,022	3.39	1,335,940
Goldfish	468	1,134	527,843	4.51	2,379,986
Israeli Carp	8	348	2,117	3.74	7,909
Totals	10,985		4,792,972		$16,698,796
Food Fishes					
Catfish	2,388	1,998	4,192,360	$1.50	$ 6,272,598
Buffalo	385	767	295,211	.44	129,907
Buffalo (Polyculture with Catfish)	72	225	16,180	.57	15,644
Cage and Raceway Trout	---	---	47,723	3.89	185,850
Cage Catfish	---	---	136,360	1.43	195,000
Totals	2,555		4,287,826		$ 6,798,799
Ornamentals	61	1,684	102,644	$8.80	$ 906,000
Fingerlings and Miscellaneous					
Largemouth Bass	4	9,884[1]	40,000[2]	$1.05[3]	$ 42,000
Channel Catfish	1,039	1,741	1,808,307	$2.66	4,814,469
White Amur	58	561	32,497	7.70	250,290
White Amur and Silver Carp Fingerling	22	1,123	24,543	$6.60	$ 162,000
Crayfish (Bait)	14	20,591[1]	283,327[2]	.03[3]	8,500
Totals	1,137		1,865,427 + 323,322 fish		$ 5,277,159
GRAND TOTALS	14,738		11,250,513 kg. + 323,322 fish		$29,590,753

1/ Fish/ha
2/ Fish
3/ Price/fish

Table 4. Commercial fish production in Arkansas — 1 July 1976 to 30 June 1977.

	Hectare	Kg./ Hectare	Total Kg.	Price/ Kg.	Total Value
Bait Fishes					
Golden Shiner	7,279	430	3,130,869	$3.52	$11,021,740
Fathead Minnows	926	337	311,969	3.56	1,111,960
Goldfish	344	633	218,180	3.48	760,400
Totals	8,549		3,660,998		$12,892,128
Food Fishes					
Channel Catfish	2,558	1,854	4,743,148	$1.32	$ 6,261,583
Blue Catfish	11	592	6,227	1.61	10,000
Buffalo	12	1,179	14,317	.57	8,190
Buffalo (Polyculture with Catfish)	---	410	55,131	.82	34,000
Trout	3	9,615	28,160	2.32	65,000
Cage Trout	---	---	36,562	2.04	74,400
Cage Catfish	---	---	294,380	1.32	388,000
Raceway Trout	---	---	46,506	2.11	98,600
Raceway Catfish	---	---	2,965	1.10	3,250
Extensive Farming					
All Species	3,414	1,586	5,485,815	1.19	6,517,500
Fee Fishing (Intensive)					
Channel Catfish	96	602	57,894	1.96	112,500
Fee Fishing (Intensive)					
Trout	3	13,364	37,354	$3.17	$ 118,900
Totals	6,121		10,867,220		$12,978,223
Ornamentals	38	1,990	74,402	$10.82	$ 811,000
Fingerlings and Miscellaneous					
	Hectare	Number/ Hectare	Total Number	Price/ Fish	Total Value
Largemouth Bass	1	9,884	12,000	$1.01	$ 11,640
Channel Catfish	349	84,291	29,404,100	.09	2,675,000
White Amur	117	1,448	170,000	1.23	204,000
Trout	---	---	50,000	.15	7,500
Totals	467		29,586,520		$ 2,899,140
GRAND TOTALS	15,175		14,593,120 kg. + 29,586,520 fish		$30,476,291

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value of 38.1%. With a favorable market and increased production cost, the value of white amur will continue to rise.

One hectare of freshwater shrimp (*Macrobrachium rosenbergii*) was raised experimentally by a fish farmer in 1978-79. This species was not raised in 1979-80 due to market demand and production costs. The only other crustacean cultured in Arkansas was the red swamp crayfish (*Procambarus clarkii*), which was raised on a limited basis for bait.

The fish farming industry of Arknasas appears to be relatively stable and capable of absorbing mild fluctuations in various production values over an extended time period. Although the industry may be stable, the problems of the past 20 years still confront the beginning fish farmer. Bailey et al. (1978) listed these problems as "nutrition, diseases, construction cost, water management, marketing, crop land allocation, and the large initial investment capital required." The fact that many fish farmers are able to overcome these problems is evidenced by the $37.7 million 1979-80 total value of the industry in Arkansas.

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THE BIOLOGY OF STRIPED BASS, *MORONE SAXATILIS*, IN BEAVER RESERVOIR, ARKANSAS

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ABSTRACT

Growth, length - weight relationship, maturation and food habits of striped bass from Beaver Reservoir were studied. No significant difference in growth in length between sexes was found. Growth of the Beaver Reservoir striped bass was similar to that of anadromous and freshwater populations. Males and females showed significant difference in length - weight relationship, and females exhibited isometric growth.

The gonosomatic indices (GSI) of males ranged from 4.50 to 7.09 and were classified as mature fish. Female striped bass with GSI of 2.62 and above had three size groups of ova and were considered as maturing and mature. The food was primarily composed of gizzard shad. Both the possible impact of striped bass on the ecosystem of Beaver Reservoir and future research are discussed.

INTRODUCTION

The striped bass (*Morone saxatilis*), was probably one of the first managed natural resources in colonial America (Pearson, 1938). Although generally regarded as an anadromous species, due to their ability to tolerate freshwater conditions, now landlocked freshwater populations exist (Scruggs, 1955). The striped bass was stocked into many Arkansas reservoirs by the Arkansas Game and Fish Commission (Pledger, 1976). The biology of this fish previously has not been investigated from Beaver Reservoir. This paper deals with the general biology of striped bass and presents data for spawning potential in Beaver Reservoir, Arkansas.

METHODS AND MATERIALS

The 11,420 ha Beaver Reservoir was impounded in 1963 on the White River. Striped bass fingerlings were first released into the reservoir in 1970, and from 1975, stocking was carried out annually (Scott Henderson, Arkansas Game and Fish Commission, *pers. comm.*). The fish for this study were collected from the War Eagle (16 fish) and the Hickory Creek (33 fish) areas by gill nets during February-March of 1979 and 1981.

Fish were brought to the laboratory and measured for total length (mm), body weight (g) and gonad weight (g). Scale samples for age and growth studies were taken from just below the lateral line at the tip of the left pectoral fin. Fish were aged by the number of annuli, and since the fish were collected in the early spring, an annulus was presumed at the edge of the scale. Scale radius and distances to annuli were measured from the cellulose-acetate scale impressions at 24x magnification. A random sample of 100 ova from each fish was measured to the nearest 0.02 mm by stereoscopic microscope fitted with ocular micrometer. Morphological characteristics of the ova in various ovum size groups were recorded. Fecundity was estimated as the total number of maturing (Group 2) and mature (Group 3) ova in both the ovaries by the wet gravimetric proportional method. Significance of statistics was expressed at the 0.01 level.

RESULTS AND DISCUSSION

Length - Weight Relationship.

The length - weight relationship was calculated as:

$$\log W = \log a + b \log L$$

where, W = fish weight (g), L = total length (mm), a = intercept, and b = regression coefficient. The estimated formulae for the males and females are:

Male	$\log W = 2.699 \log L - 4.059$
Female	$\log W = 2.903 \log L - 4.624$

There was significant difference between the sexes ($F_{2,45} = 5.91$), and the females exhibited isometric growth (b = 3.0).

Age and Growth.

Striped bass belonging to age groups IV - VIII were collected, and age groups IV and VI comprised 64% of the collections. Among the males age group VI was dominant (57%), while age group IV was abundant (37%) of the females (Table 1). Lengths at the end of each year of life, i.e. at the time of annulus formation, were back-calculated by the formula:

$$L' = C + (S'/S)(L-C)$$

where L' = estimated length at an annulus, L = fish length at capture, S = scale radius, S' = distance to annulus, and C = intercept.

Table 1. Average back-calculated lengths of striped bass from Beaver Reservoir.

		Total length (mm) at annulus							
Age-group	Number of fish	1	2	3	4	5	6	7	8
					Males				
IV	4	187	222	315	390				
V	2	139	204	296	359	394			
VI	12	167	270	367	461	539	593		
VII	3	194	269	352	475	604	661	719	
Weighted mean		168	254	348	440	533	610	719	
					Females				
IV	10	148	229	315	377				
V	6	138	221	308	396	447			
VI	5	158	271	370	455	523	580		
VII	5	180	254	400	494	589	674	762	
VIII	1	145	256	409	563	727	819	864	878
Weighted mean		153	242	343	428	527	644	779	878

Table 2. Comparison of striped bass growth (sexes combined) from various regions.

Locality and Reference	Calculated total length (mm) at annulus							
	1	2	3	4	5	6	7	8
Beaver Reservoir, Ar. (Present study)	161	247	345	438	532	638	751	878
California (Scofield 1931)*	114	266	397	484	565	630	690	
New England States (Merriman 1941)	134	252	391	482				
Santee-Cooper Reservoir, South Carolina (Scruggs 1955)	100	379	495	564	638	699	765	828
Santee-Cooper Reservoir, South Carolina (Stevens 1957)*	217	402	506	584	658	728	772	
California (Robinson 1960)	111	266	416	533	622	698	758	813
Chesapeake Bay, Maryland (Mansueti 1961)	139	315	412	481	565	661	764	822

* Data from Mansueti (1961)

The intercept (C) values for male and female were calculated from the scale radius - total length relationships ($L = C + bS$) and were 79.22 and 61.69, respectively. Back-calculated lengths by sex, age group, and weighted average are given in Table 1. There were no significant differences in the lengths between the sexes in the first six years of life; comparison among the seventh year of life was not made due to inadequate sample size.

Comparison from various sources (Table 2) of striped bass growth during the first eight years of life showed that, in general, an average annual length increment of 106 mm for freshwater populations (Present study; Scruggs, 1955; Stevens, 1957) was similar to that of the marine (anadromous) populations - 102 mm (Scofield, 1931; Merriman, 1941; Robinson, 1960; Mansueti, 1961). Differences in average size of the fish in relation to age (Table 2) were probably due to the type of gear used and the sample sizes. Overall striped bass growth was similar for all the regions (Mansueti, 1961).

Food Habits.

A total of 49 stomachs (21 males and 28 females) were examined, with 12 stomachs (24%) being empty. The food was mainly composed of fishes; most of the identifiable diet was gizzard shad (*Dorosoma cepedianum*), contributing 96.7% to the diet. A single stomach contained white crappie (*Poxomis annularis*). Partially digested fish remains were classified as gizzard shad based on body shape and ribs. The size of the gizzard shad ranged from 88 to 187 mm TL; the single white crappie was 155 mm TL.

It was reported that adult striped bass feed primarily on fishes, gizzard shad, threadfin shad (*D. petenense*), blueback herring (*Alosa aestivalis*), alewife (*A. pseudoharengus*), minnows, and young striped bass (Merriman, 1941; Trent and Hassler, 1966; Stevens, 1966). In Beaver Reservoir, gizzard shad is the most abundant forage for sportfishes. An investigation of the abundance and fluctuations of gizzard shad and of the predator-prey relationship of the fishes in the reservoir is needed to evaluate the effect of the stocking of striped bass on other sportfishes.

Maturation.

All the male striped bass, age groups IV-VII, had large whitish testes, and milt was extruded with pressure on the abdomen. The gonosomatic indices ranged from 4.50 to 7.09, and the fish were classified as mature. It was reported that some 2-year olds and all 3-year olds and older males attain sexual maturity (Merriman, 1941; Scruggs, 1955; Mansueti, 1961).

Ovum diameter frequencies from all the females used in this study (Fig. 1) showed three distinct groups of ova; 0.06 - 0.24 mm (average, 0.16 mm), 0.26 - 0.56 mm (0.36 mm), and 0.58 - 1.08 mm (0.73 mm). The ova in group 1 were translucent with visible nucleus; in group 2 the ova were granular to opaque in appearance due to yolk deposition; and the group 3 ova were completely opaque, with many lying free in the lumen of the ovary. These morphological features of the ova were similar to those reported by Lewis (1962).

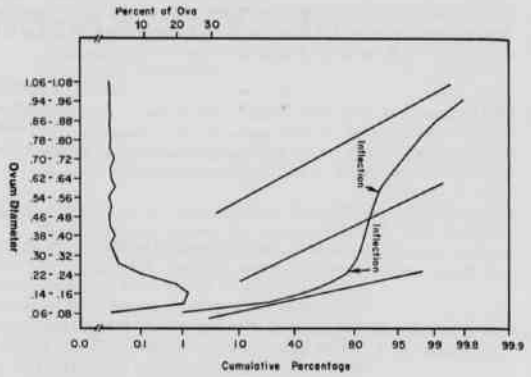

Figure 1. Ovum diameter frequencies and cumulative percentage distributions on probability scale.

Gonosomatic index and ovum distribution are given in Table 3. All the ovaries contained group I ova. The fish with group 2 and 3 ova were classified as maturing - mature and capable of spawning in spring. The fish with GSI from 2.62 to 4.86 contained group 2 and 3 ova; therefore, it was assumed that the fish 7-years old and older attain sexual maturity. Since these findings are based on few fish, large sample size, inclusive of various age and length groups, are needed to establish definite age and length at which striped bass reach maturity. Based in part on percentage of fish in spawning and non-spawning condition before and after the spawning season, Scofield (1931) considered striped bass with ova exceeding 0.29 mm as spawners in California. Jackson and Tiller (1952) stated that the Chesapeake Bay fish with ova averaging 0.75 mm or more in diameter in early spring could be expected to spawn that year. Lewis (1962) considered striped bass with type 2 (0.16 0.30) and type 3 (0.33 - 1.00 mm) ova as mature. The striped bass of our study with GSI of 2.62 or more conformed to the findings of Lewis (1962). Therefore, we presume that the fish collected in February and March with GSI of 2.62 or more and group 2 and 3 ova are potential spawners in the spring.

All the published literature indicated that striped bass spawn in spring (Scruggs, 1955; Lewis, 1962; Farley, 1966; Nichols and Miller, 1967; Turner, 1976). Regarding age of females, spawning varied in different regions. Merriman (1941) reported both spawners and non-spawners in age groups IV, V, and VI. Similar findings were reported

Table 3. Gonosomatic index (GSI) and ovum distribution by age groups for the Beaver Reservoir striped bass.

Age group	Number of fish	GSI	Ovum distribution
IV	8	0.76 (0.49-1.34)	Group 1 ova in 25% of fish Group 2 ova in 75% of fish
V	6	1.37 (0.34-1.37)	Group 1 ova in 50% of fish Group 2 ova in 17% of fish Group 2 & 3 ova in 33% of fish
VI	5	0.59 (0.43-0.85)	Group 1 ova in 80% of fish Group 2 ova in 20% of fish
VII	5	2.32 (0.43-4.86)	Group 2 ova in 40% of fish Group 2 & 3 ova in 60% of fish
VIII	1	2.78	Group 2 & 3 ova

by Scofield (1931). These workers indicated spawning by all females in age group VII while Lewis (1962) reported it in age group V.

The striped bass is an anadromous fish that ascends rivers for spawning; however, freshwater populations were established due to impoundment (Scruggs, 1955) and by stocking practices. The question arises as to whether the fish has the ability to complete a full life cycle and to establish self-perpetuating populations in Beaver Reservoir. Striped bass were stocked in Beaver Reservoir in 1970 and annually since 1975. The gonosomatic indices and the presence of groups 2 and 3 ova with yolk indicate that the striped bass attain maturity and are capable of spawning in the Beaver Reservoir. The single age-group VIII fish (GSI = 2.78) belonged to the 1973 year-class, and the fish were not stocked in Beaver Reservoir in that year. It is probable that some fast growing fish stocked in 1970 spawned in 1973, resulting in age-group VIII fish in 1981. Future investigation of obtaining spent fish, eggs and larvae is recommended to evaluate spawning of striped bass in Beaver Reservoir. Scruggs (1955) reported on the natural reproduction of striped bass from the Santee-Cooper Reservoir, South Carolina, based on the occurrence of mature fish, eggs and larvae.

Fecundity.

Fecundity, total number of group 2 and 3 ova in both the ovaries, was estimated by wet gravimetric method from 5% of the total ovary weight (Table 4). Group 3 ova comprised 95% of the estimated fecundity. Based on hatchery records, Merriman (1941) reported the range of eggs per female as 11,000 - 1,215,000 with the majority of fish producing 100,000 - 700,000 eggs.

Table 4. Fecundity estimates for the Beaver Reservoir striped bass.

Age group	Total length (mm)	Weight (g)	GSI	Fecundity
V	405	985	3.05	85,800
V	417	980	3.37	94,220
VII	753	5,920	4.86	1,006,040
VII	770	5,675	3.10	548,700
VII	806	6,220	2.42	516,840
VIII	870	9,852	2.78	957,700

General Remarks.

The impact of the striped bass on the ecosystem of Beaver Reservoir needs to be studied more. If the females are capable of producing viable ova, it may be possible for natural reproduction to occur since mature males are readily found. Also, Pledger (1976) states that some of the striped bass in Beaver Reservoir may be of the Santee-Cooper Reservoir stock, which includes a landlocked, naturally reproducing population. If the fish from Beaver Reservoir are from this population, they are genetically similar and may be able to reproduce in a totally freshwater environment. Further studies need to be conducted on Beaver Reservoir to determine if females with spent ovaries are present and to find if any larvae are present in the tributaries of Beaver Reservoir.

It is also important to determine the impact of striped bass on the shad population. The food habits of this study show that striped bass consume primarily shad. It is important to fisheries management to determine both how effectively these fish are feeding on shad and what effect it has on other sport fish also utilizing shad as forage.

Another aspect of striped bass biology warranting further investigation is the survival of this species in Beaver Reservoir. Stocking of the reservoir has been done annually since 1975, but it is not known how well these fish are surviving. Thus, a study is needed on the mortality, due to natural causes and sport fishing, of the stocked individuals. Also, if these fish are reproducing in the reservoir, larval survival and percent of larvae reaching adult size need to be investigated.

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OXIDATION OF NATIVE AND MODIFIED HEMOGLOBIN AND MYOGLOBIN BY SODIUM NITRITE. EFFECT OF INOSITOL HEXAPHOSPHATE

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ABSTRACT

Native and modified hemoglobin, myoglobin and α and β hemoglobin subunits were oxidized by sodium nitrite at pH 6. The experiments were carried out under oxy and deoxy conditions with and without inositol hexaphosphate (IHP).

It is shown (a) that under oxy condition low concentration of IHP inhibits the oxidation of native hemoglobin only. However, high concentration of IHP inhibits the oxidation of both myoglobin and modified hemoglobin (digested or β-93-SH groups blocked). This inhibition is partially counteracted by high oxygen pressure. (b) Under deoxy condition the oxidation rates of all hemeproteins studied are significantly faster than that of native hemoglobin. IHP inhibits the oxidation of all except the myoglobin and hemoglobin subunits.

It is concluded that although the IHP inhibitory effect on hemoglobin oxidation by nitrite can be explained by the shift of the R⇄T conformational equilibrium towards T conformation, some other structural changes such as alteration in molecular surface charges must occur to account for the effect of IHP on the oxidation of heme proteins devoid of heme-heme interaction.

INTRODUCTION

Hemoglobin oxidation by agents such as potassium ferricyanide, hydrogen peroxide and copper is significantly faster in the deoxy (T) than in the oxy (R) conformation. On the contrary, the oxidation of hemoglobin by sodium nitrite is inhibited by both deoxygenation and inositol hexaphosphate (IHP) which shift the molecular conformational equilibrium towards T conformation.

The hemoglobin oxidation by sodium nitrite has been known for over a century (Gamgee, 1869). Although during this time many aspects of the reaction have been studied (Meir, 1925, Jaenig and Jung, 1970), its exact mechanism is not fully understood. The discovery of the effect of organic phosphate on the functional properties of hemoglobin has stimulated more work in this area.

It has been assumed, although not directly proven, that the inhibitory effect of IHP on the oxidation reaction is related to the stabilization of the T conformation (Tomoda, et al., 1977). However, blockage of β-93-SH groups by iodoacetamide which conserves most of the heme-heme interaction (Taylor, et al., 1966), accelerates the oxidation reaction under deoxy condition leaving the inhibitory effect of IHP intact (Mansouri, 1979). This work was undertaken to explore further the mechanism of this reaction.

MATERIALS AND METHODS

All oxidation reactions were carried out at 25°C. All buffers contained 10^{-4} M ethylenediamintetraacetic acid (EDTA). The hemoglobin samples were stripped of organic phosphates by the method of Antonini (Antonini and Brunori, 1971). The following chemicals were obtained from Sigma Chemical Co., St. Louis, MO: bis (2-hydroxyethyl) iminotris (hydroxymethyl) methane or bis-tris, diisopropylfluorophosphate-treated carboxypeptidase A (CPA), catalase, dl-dithiothreitol, 5,5'-dithiobis-(2-nitrobenzoic acid), iodoacetamide, p-chloro-mercuribenzoate (PCMB) and sperm whale myoglobin. Inositol hexaphosphate (IHP) was purchased from P-L Biochemicals, Milwaukee, WI.

Hemoglobin A was purified from freshly drawn human citrated blood by ion exchange chromatography (Winterhalter and Huehns, 1964) (600 × 25 mm column for 20 ml of blood). Pure fractions were concentrated and dialyzed against 0.05 M tris buffer at pH 8.6.

Hemoglobin α and β subunits were isolated by the method of Bucci and Fronticelli (1965) except that the regeneration of the −SH groups was carried out by incubation of α-PCMB and β-PCMB with 20 mM dithiothreitol under nitrogen for 30 min in the presence of catalase (Ikeda-Saito, 1977). The purity of the subunits was checked by cellulose acetate electrophoresis (Marengo-Rowe, 1965).

Commercial sperm whale ferric myoglobin was dissolved in 2-3 mls of 0.05 M bis-tris buffer at pH 6. Slight molar excess of sodium dithionite/heme was added to reduce the heme iron. The sample was then applied on a G-25 spehadex column (300 × 12 mm) equilibrated with the same buffer to eliminate the excess of dithionite.

The blockage of β-93 cysteine residues was carried out at pH 7.8 in the presence of 10 fold molar excess of iodoacetamide/heme. Then the sample was incubated in the dark at 20°C (Winterbourn and Carrell, 1977). It was applied on cellulose acetate electrophoresis to prevent significant chain separation. The absence of the free thiol groups was tested by Ellman's method (1959).

Hemoglobin was digested by CPA following exactly the method described by Moffat (1971). The product of digestion was applied first on a G-25 Sephadex column, to free it from small molecules, and then on cellulose acetate electrophoresis, to demonstrate its homogeneity. No amino acid analysis was carried out on the portion containing the carboxy termini.

Two ml of 0.2 mM native or modified hemoglobin, myoglobin or hemoglobin subunits in 0.05 M bis-tris buffer, pH 6, was placed in a 1 cm light path quartz cuvette. Twenty μl of 20 mM sodium nitrite solution (heme/nitrite molar ratio = 2) was added with a micropipette (Corning, Corning, New York) and mixed immediately. The increase of light absorbance at 631 nm (proportional to methemoglobin formation) was monitored by a double beam Beckman spectrophotometer, model 35, at 25°C with the recorder started when the sodium nitrite was added. All experiments under deoxy condition were carried out in a 1 cm light path tonometer. The hemoglobin solution was deoxygenated using a high vacuum pump by the method of Rossei-Fanelli and Antonini (1958). Spectrum between 700-500 nm was obtained to ascertain complete deoxygenation. One hundred μl of 4 mM sodium nitrite solution previously deoxygenated by nitrogen wash was injected into the tonometer with a microsyringe (Hamilton, Reno, NV) but not yet mixed with hemoglobin. Further vacuum was applied to eliminate any oxygen that entered during the injection

process. The tonometer was brought to 25°C, and the two solutions were mixed vigorously while the recorder was started simultaneously. The reaction was followed spectrophotometrically at 631 nm.

RESULTS

Oxidation of Oxyhemoglobin and Oxymyoglobin With and Without IHP.

Hemoglobin and myoglobin were oxidized in air with and without varying concentration of IHP. Figures 1 and 2 show that the oxidation rate of myoglobin is slower than that of hemoglobin. IHP inhibits the oxidation reaction. The inhibition depends on the concentration of IHP for both hemeproteins. However, for the same degree of inhibition a much lower concentration of IHP is needed for hemoglobin.

Effect of High Oxygen Pressure on Oxidation.

Because of marked difference in oxidation rate of hemoglobin under oxy and deoxy conditions, the effect of high concentration of oxygen was tested. Figures 3 and 4 show the oxidation kinetics of hemoglobin and myoglobin in air and under one atmosphere of oxygen. High oxygen pressure not only accelerates the rate of oxidation, but also partially counteracts the inhibitory effect of IHP on the hemoglobin oxidation.

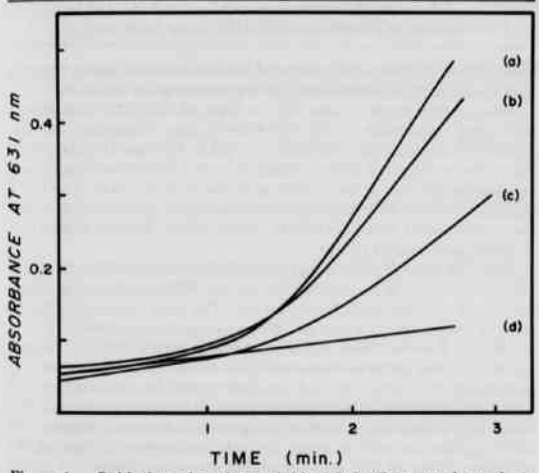

Figure 1. Oxidation of oxyhemoglobin (nitrite/heme molar ratio = 2 in all experiments) with no IHP (a) and in the presence of IHP/heme molar ratio of 0.1 (b); 0.2 (c); and 1.0 (d).

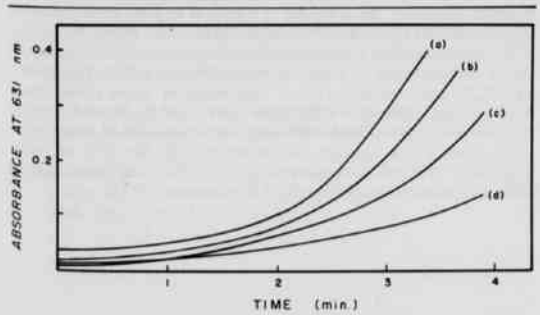

Figure 2. Oxidation of oxymyoglobin with no IHP (a) and in the presence of IHP/heme molar ratio of 0.5 (b); 1.0 (c); and 5 (d).

Oxidation of Modified Hemoglobins Under Deoxy Condition.

Two types of modified hemoglobin, iodoacetamide reacted hemoglobin with normal heme-heme interaction, and carboxypeptidase A digested hemoglobin with little or no heme-heme interaction, were oxidized under deoxy condition. Figure 5 shows that both of these hemoglobins are oxidized rapidly under deoxy condition (unlike native hemoglobin), but the addition of IHP inhibits both reactions (like native hemoglobin).

Oxidation of Myoglobin and Hemoglobin Subunits Under Deoxy Condition With and Without IHP.

Because of similarity of myoglobin and hemoglobin subunits and the lack of heme-heme interaction, these heme proteins were oxidized under deoxy condition in the absence of IHP (Fig. 6) and in the presence of IHP (Fig. 7). Due to precipitation of α PCMB and α chains in the presence of IHP, the oxidation of these subunits could not be carried out with IHP. In both figures the oxidation curve of native hemoglobin is inserted for comparison.

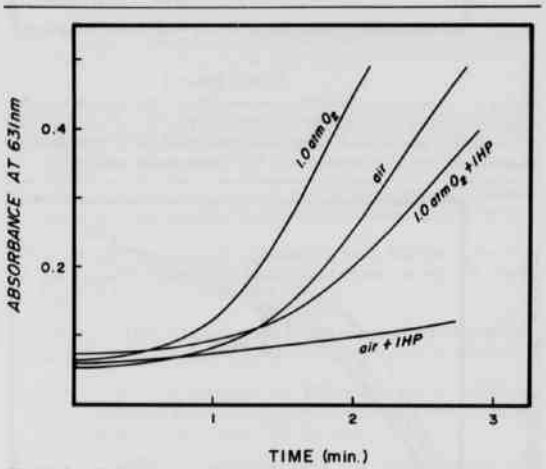

Figure 3. Oxidation of oxyhemoglobin in air and under 1.0 atmosphere of oxygen with and without IHP. IHP/heme molar ratio = 0.5. Note that oxygen increases the rate of the oxidation reaction as well as offsets largely the inhibitory effect of IHP.

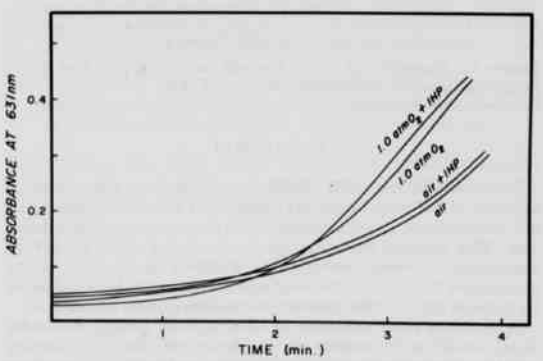

Figure 4. Oxidation of oxymyoglobin under exactly same conditions as in Figure 3.

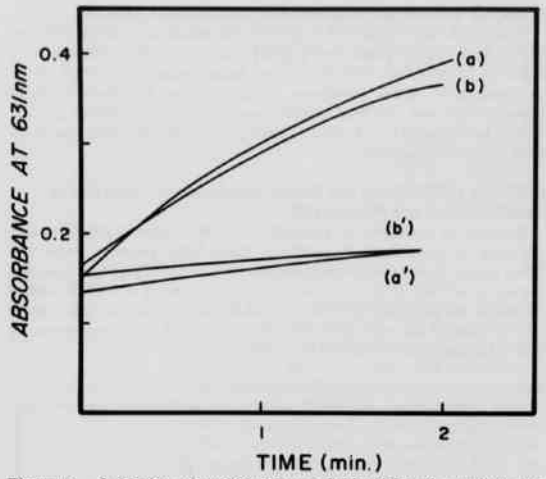

Figure 5. Oxidation of modified hemoglobin (CPA digested) under deoxy conditions without IHP (a) and with IHP (a'). Curves (b) and (b') represent oxidation of hemoglobin with (β-93-SH groups blocked) without and with IHP respectively. IHP/heme molar ratio = 0.5.

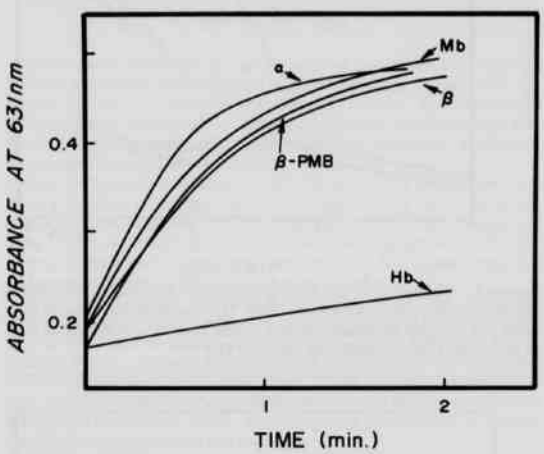

Figure 6. Oxidation of deoxy hemoglobin, myoglobin and hemoglobin subunits (No IHP added). PMB = PCMB.

DISCUSSION

The results of this study clearly demonstrate that although small amounts of IHP only inhibit the oxidation of native hemoglobin and not of myoglobin, larger amounts inhibit the oxidation of the latter as well. This suggests that although the inhibitory effect of IHP on hemoglobin oxidation seems to be mediated by the shift of the quarternary R⇄T conformational equilibrium as has been suggested by Tomoda (1977), other possible mechanisms can not be ruled out.

In fact, the rapid oxidation of CPA digested hemoglobin under deoxy condition by sodium nitrite emphasizes that the molecular conformation is an important rate determining factor. It is disturbing that under deoxy condition, a small amount of IHP inhibits the oxidation of this modified hemoglobin as well. In this regard one can only

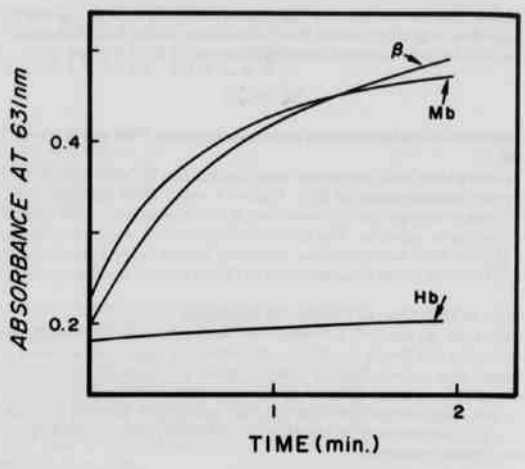

Figure 7. Oxidation of deoxyhemoglobin, myoglobin and hemoglobin β-subunits in the presence of IHP. IHP/heme molar ratio = 0.5.

assume that in spite of digestion of the β-C-termini, there remains perhaps some heme-heme interaction accounting for this effect.

Another important element also in favor of the R⇄T equilibrium shift being responsible for the IHP effect is that oxygen not only significantly increases the oxidation rate but it also partly counteracts the inhibitory effect of IHP. It should be noted, however, that oxygen can modify the rate of the oxidation by mechanism other than R⇄T equilibrium shift, such as direct participation in the oxidation as has been reported by Kakizaki (1964), Smith (1970), Rodkey (1976) and Wallace and Caughey (1975).

Although several factors suggest mechanisms other than the R⇄T equilibrium shift to be responsible for the IHP effect on the oxidation, none of them exclude the former. The most important among these is the inhibitory effect of IHP on myoglobin oxidation. It is to be noted, however, that significantly larger amounts of IHP are needed to bring about the same effect on myoglobin oxidation as that on hemoglobin oxidation. The insensitivity of the oxidation rate of iodoacetamide reacted hemoglobin (β-93-SH groups blocked) to IHP under oxy condition is another factor which does not support the R⇄T equilibrium shift as being the only mechanism explaining the inhibitory effect of IHP on hemoglobin oxidation. Finally, it seems that the addition of a large amount of IHP to the oxidation reaction can be a nonspecific salt effect. But this is not the case because an equivalent amount of NaCl does not change the rate of the oxidation reaction. However, the presence of 5 units of heparin in the reaction mixture inhibits significantly the oxidation rate (not shown here).

It is concluded that although the inhibitory effect of IHP on hemoglobin oxidation can be explained mostly by the shift of the quaternary R⇄T equilibrium towards T conformation, some subtle structural changes other than R⇄T shift must occur to account for the IHP effect on the oxidation of heme proteins devoid of heme-heme interaction. These changes are rather specific for IHP or other negatively charged molecules suggesting that the alteration of molecular surface charges is a likely mechanism.

ACKNOWLEDGMENTS

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NON-MEASLES HEMADSORPTION IN A CELL LINE PERSISTENTLY INFECTED WITH MEASLES VIRUS (BGM/MV)

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ABSTRACT

Adsorption of Rhesus monkey erythrocytes to the plasma membranes of measles virus-infected cells is frequently carried out to detect the presence of plasma membrane-associated measles virus hemagglutinin. The hemagglutinin is a viral genome-coded structural glycoprotein of the measles virion that is associated with the plasma membrane of the host cell during measles virus replication. BGM/MV, a non-virogenic line of African green monkey kidney cells persistently-infected with measles virus, adsorbed Rhesus monkey erythrocytes in an inverse fashion relative to the number of cells present in the culture and the time post-seeding. Serological studies employing the hemadsorption-inhibition and membrane immunofluorescence assay procedures, suggested that this phenomenon was not mediated by the viral hemagglutinin. Assays for Simian virus-5 and mycoplasma, contaminating agents that induce erythrocyte adsorption, were negative. Incubation of BGM/MV cells at 33°C or with graded concentrations of fetal calf serum, to stimulate the metabolism of resting (G_o) cells, suggested that adsorption was related to a phase(s) of the cell growth cycle other than G_o, for adsorption was prolonged and stimulated in a dose-response fashion, respectively. Comparative adsorption studies employing the parent cell line (BGM), not infected with measles virus, were performed using various species of erythrocytes. While both cell lines adsorbed Rhesus monkey erythrocytes in an inverse fashion relative to cell density, differences were noted in the adsorption of some of the other species of erythrocytes. These data suggest that Rhesus monkey erythrocyte adsorption to BGM/MV cells was mediated by a receptor(s) of cellular origin.

INTRODUCTION

The adsorption of erythrocytes to the plasma membranes of cultured cells, hemadsorption (HAD), is frequently used to detect cell surface-associated viral antigens. Care must be taken in the interpretation of HAD results, as a number of apparently uninfected cell lines have been found to spontaneously adsorb various species of erythrocytes (Franks et al., 1963; Kano and Milgrom, 1965; Neuman and Tytell, 1965).

This report describes studies involving the BGM/MV cell line, which consists of the BGM cells (African green monkey kidney cells) (Barron et al., 1970) which are persistently infected with a mouse-adapted neurotropic strain of measles virus. The cell line was established by Menna et al. (1975a) and has been well characterized (Menna et al., 1975a,b; Flanagan and Menna, 1976). As determined by indirect immunofluorescence assay, > 99% of the cells contained cytoplasmic measles virus antigens, whereas, less than 1% of the cells possessed detectable levels of cell surface measles antigens (Menna et al., 1975a). Infectious measles virus was not recovered from the cells, nor could it be induced by treating the cells with various metabolic inhibitors or by enucleating the cells with cytochalasin B (Menna et al., 1975a). Although treatment of confluent cell monolayers with metabolic inhibitors failed to induce the synthesis of infectious measles virus, several of the metabolic inhibitors when added to BGM/MV cells induced the expression of measles cell surface antigens (Menna et al., 1975a; Flanagan and Menna, 1976).

Studies by May and Menna (1979) revealed changes in the stable virus host cell relationship characteristic of the BGM/MV line of cells. An apparent cyclic expression of cytopathic effect occurred in concert with changes in the percent of cells with intracellular and cell surface measles antigens. In the course of these studies it was noted that the BGM/MV cells exhibited spontaneous (non-induced) HAD activity of Rhesus monkey erythrocytes inversely to the total number of cells present in the culture. The results of experiments carried out to characterize this phenomenon are discussed in this report.

METHODS AND MATERIALS

Cell Lines.

BGM, a stable line of African green monkey kidney cells (Barron et al., 1970) were passaged weekly by trypsinization. The cells were seeded in Eagles' Minimum Essential Medium (EMEM) supplemented with 10% fetal calf serum (FCS) and 50 ug per ml of gentamicin. BGM cell cultures were incubated at 37°C in an atmosphere of 5% CO_2.

The BGM/MV cell line was derived by the co-cultivation of BGM cells with mouse brain cells prepared from C3H mice infected *in vivo* with a neurotropic strain of measles virus (Menna et al., 1975a). BGM/MV cells are persistently infected with measles virus and are morphologically and antigenically BGM-like cells (Menna et al., 1975b).

BGM/MV cells were passaged every four days by trypsinization and were seeded in EMEM supplemented with 10% FCS and gentamicin at a concentration of 50 ug per ml. Unless otherwise noted, BGM/MV cells were incubated at 37°C in an atmosphere of 5% CO_2.

Viruses.

Measles virus, Edmonston strain (MV-500E), was obtained from Dr. T. D. Flanagan, Buffalo, N.Y. Stock virus consisted of clarified infectious BGM cell lysates.

Stock Simian virus-5 (SV-5), originally obtained from the American Type Culture Collection, was prepared as an infectious clarified BGM cell lysate.

Antisera.

African green monkey serum directed against measles virus anti-

gens (Gallagher and Flanagan, 1976) was obtained from Dr. Flanagan. The antiserum was exhaustively absorbed with BGM cells before use.

Rabbit antisera to SV-5 was obtained from Microbiological Associates, Bethesda, MD. Prior to use, the antisera was exhaustively absorbed with BGM cells.

Fluorescein isothiocyanate (FITC)-labeled goat antiserum to human IgG and FITC-labeled goat antiserum to rabbit IgG (Hyland Co., Costa Mesa, CA.) were used in the indirect immunofluorescence assays for measles virus antigens and SV-5 antigens, respectively.

Erythrocytes.

Rhesus monkey erythrocytes were provided by Drs. D. E. Hill and A. A. Krum, University of Arkansas for Medical Sciences. Guinea pig, chicken, rabbit, and human group-O erythrocytes were provided by the Department of Microbiology and Immunology, University of Arkansas for Medical Sciences.

Cell Enumeration.

Monolayer cultures of BGM/MV cells were trypsinized, suspended in EMEM, and cells were counted using a Spencer hemacytometer.

Hemadsorption Assay.

Hemadsorption assays were performed using the procedure of Menna et al. (1975a). Briefly, cell cultures were washed three times in EMEM, and then were incubated at room temperature for 60 min with an appropriate volume of a 0.5% Rhesus monkey erythrocyte suspension prepared in EMEM. The cell cultures were then washed three times with EMEM and were observed microscopically (100 ×) for adherent erythrocytes. Cells with three or more adherent erythrocytes were considered HAD-positive. The degree of hemadsorption was quantified in replicates of three cultures, and the mean percent HAD-positive cells was determined.

Hemadsorption-Inhibition (HADI) assay.

Hemadsorption-inhibition assays were performed using the procedure described by May and Menna (1979) to determine the specificity of the adsorption of Rhesus monkey erythrocytes to the plasma membranes of BGM/MV cells. Cultures of BGM/MV, BGM, and BGM cells lytically-infected with the MV-500E strain of measles virus, were washed three times with EMEM. Then 1 ml volumes of varying dilutions of heat-inactivated (56° C for 30 min) African green monkey antiserum to measles virus antigens was added to replicate cultures of each series. As controls, replicate cultures of each series were treated with pre-immune African green monkey serum or were mock-treated with EMEM. The cell cultures were then incubated for 1 hr at 37° C, washed three times with 1 ml volumes of EMEM, and an HAD assay employing Rhesus monkey erythrocytes was carried out as described above.

Membrane Immunofluorescence Assay.

BGM/MV cells were assayed for membrane-associated measles virus antigens using the procedure of Menna et al. (1975a). Briefly, unfixed BGM/MV cells, grown on 9 × 22 mm coverslips (Bellco Biological Glassware, Vineland, N.J.) were rinsed three times with phosphate buffered saline (PBS, pH 7.2) and were then treated for 30 min at 4° C with a 1:10 PBS dilution of African green monkey antiserum to measles virus antigens (heat-inactivated, 56° C for 30 min). As controls, BGM/MV cells treated with pre-immune African green monkey antiserum, or with PBS alone, were assayed in parallel. In each assay, to assess the activity of the anti-measles virus antiserum, a positive control was assayed in parallel, which consisted of BGM cells lytically-infected with the MV-500E strain of measles virus and uninfected BGM cells. Following incubation, all of the cultures were washed for 20 min in cold PBS to remove unreacted antiserum. The cultures then were treated with FITC-labeled goat antiserum to human IgG and incubated at 4° C for 20 min. The cell cultures were washed in cold PBS for 10 min, the coverslips were mounted in buffered glycerol (1 part glycerol to 9 parts PBS), and the cells were observed for membrane immunofluorescence using a Zeiss microscope equipped with a fluorescence epi-illuminator.

Immunofluorescence Assay for Intracellular Antigens.

The indirect method of immunofluorescence was used for detecting SV-5 antigens in BGM/MV cells. BGM/MV cells grown on 9 × 22 mm coverslips were fixed in acetone at 4° C for 10 min. Following fixation, the coverslips were air dried at room temperature and washed for 5 min in cold PBS. Appropriately diluted rabbit antiserum to SV-5 antigens was then added to the cell monolayers, and the cultures were incubated for 30 min at 37° C. Additional acetone-fixed monolayers of BGM/MV cells were assayed in parallel, using pre-immune rabbit serum and PBS alone. Also, in each assay, a virus control consisting of SV-5-infected BGM cells and a negative-control consisting of uninfected BGM cells were assayed in parallel. Following incubation, the cell monolayers were washed for 20 min in cold PBS and treated with appropriately diluted FITC-labeled goat antisera to rabbit IgG for 30 min at 37° C. Then, they were washed for 20 min in cold PBS, mounted in buffered glycerol, and observed using a Zeiss microscope equipped with a fluorescence epi-illuminator.

Assay of Cell Viability.

Viability of BGM/MV cells was assessed using the trypan blue (Sigma Chemical Co., St. Louis, MO.) exclusion staining procedure of Merchant et al. (1964).

RESULTS

Although spontaneous HAD activity occurred during both the cytopathic and non-cytopathic phases of the cyclic expression of the measles virus infection of the BGM/MV cells, only the non-cytopathic phases were investigated. This was necessitated by the difficulty in quantifying cells during periods of syncytial cell expression. The results of a representative experiment demonstrating the inverse relationship between cell number and the spontaneous adsorption of Rhesus monkey erythrocytes are shown in Figure 1.

BGM/MV cells were seeded at a concentration of 2.5×10^4 cells per ml, and the cultures were incubated at 37° C in an atmosphere of 5% CO_2. At daily intervals for four days, replicates of three cultures were harvested for total cell determination, and three cultures were harvested for determination of the percent hemadsorbing cells. Greater than 99% of the BGM/MV cells adsorbed Rhesus monkey erythrocytes during the initial 48 hrs post-seeding (PS). Further incubation of the cells at 37° C resulted in an increased number of cells and a pronounced decrease in HAD activity. At 72 and 96 hrs PS, successive doublings occurred essentially in the number of cells while the HAD activity had decreased to 20% and <1%, respectively. Cell viability at all times was >95%.

The apparent association of cell growth density with the expression of cell surface receptors for Rhesus monkey erythrocytes was further investigated by comparing the growth rate and HAD activity of BGM/MV cells grown at 33° C and 37° C. BGM/MV cells were seeded at 8×10^4 cells per ml. One-half of the cultures were incubated at 37° C in an atmosphere of 5% CO_2; the remaining cultures, in an identical atmosphere at 33° C. At daily intervals thereafter for

five days, three cultures from each series were harvested for enumeration of cells and three for HAD assay. The results of this experiment are shown in Figure 2. Cells grown at 33° C replicated at a slower rate and had an elevated HAD activity for an extended period of time when compared with cells grown at 37° C. At 96 hrs PS, <1% of the cells grown at 37° C were HAD-positive, whereas > 99% of the cells grown at 33° C were positive. At 120 hrs PS, the HAD activity of the cultures grown at 33° C had decreased by approximately 75% from the level observed during the initial 96 hrs PS.

To determine if the spontaneous HAD activity was measles virus-specific, an HADI assay was performed using heat-inactivated (56° C for 30 min) African green monkey serum directed against measles virus antigens. Treatment of replicate monolayers of BGM/MV cells at 24 hrs PS for 1 hr at 37° C with the monkey anti-measles serum failed to block or reduce the adsorption of Rhesus monkey erythrocytes to the cells. But the antiserum blocked the adsorption of Rhesus monkey erythrocytes to the parent BGM cells which were lytically-infected with the MV-500E strain of measles virus. To further document that the HAD activity was not mediated by measles virus hemagglutinin, BGM/MV cells were examined daily PS for four days for the presence of plasma membrane-associated measles virus antigens by the indirect immunofluorescence assay procedure employing unfixed cells. No correlation was observed between the cell density-associated HAD activity of the cells and membrane immunofluorescence, for the percent of cells spontaneously expressing antigen failed to fluctuate with time PS.

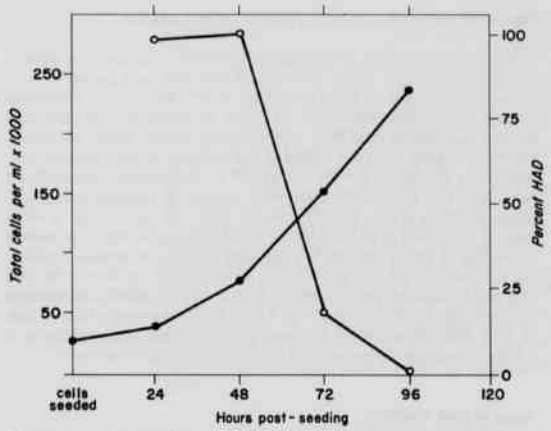

Figure 1. The number of cells per ml and the percent of cells adsorbing Rhesus monkey erythrocytes during the growth of BGM/MV cells. BGM/MV cells were seeded at 2.5 × 104 cells per ml in growth medium and were incubated at 37° C in an atmosphere of 5% CO_2. All points represent the mean of three replicates; ●—●, total number of cells per ml; 0—0, percent HAD-positive cells.

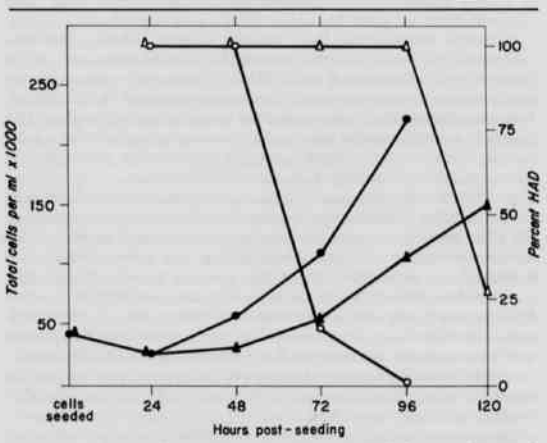

Figure 2. Comparison of the rate of growth and the capacity to adsorb Rhesus monkey erythrocytes of BGM/MV cells grown at 33° C and 37° C. All points represent the mean of three replicates; ●—●, total cells per ml at 37° C; 0—0; percent HAD-positive cells at 37° C; ▲—▲ total cells per ml at 33° C; △—△ percent HAD-positive cells at 33° C.

To further characterize the non-measles virus-mediated density-dependent HAD activity of BGM/MV cells, comparative adsorption studies were performed using the parent uninfected cell line, BGM/MV and BGM cells were seeded at a concentration of 2.5 × 10^4 cells per ml and the cell cultures were incubated at 37° C in an atmosphere of 5% CO_2. At 24 and 96 hrs PS, standard HAD assays were performed using replicates of three cultures of each cell line per species of erythrocyte tested. These erythrocytes were guinea pig, chicken, human group-O, rabbit, and Rhesus monkey. The results of this experiment are shown in Table 1. BGM/MV cells adsorbed only two species of erythrocytes, Rhesus monkey and human group-O, and only at 24 hrs PS. In contrast, the parent BGM cell line adsorbed all species of erythrocytes except guinea pig. Of particular interest is that the parent BGM cell line also adsorbed Rhesus monkey erythrocytes inversely to the time PS, and presumably inversely to cell number.

Guinea pig and chicken erythrocytes failed to adsorb to the BGM/MV cells at 24 hrs PS, a time at which >99% of the cells were capable of adsorbing Rhesus monkey erythrocytes. This failure suggested that the cell density-dependent HAD of Rhesus monkey erythrocytes by BGM/MV cells was not due to contamination with SV-5, a virus that will induce the HAD of both guinea pig and chicken erythrocytes (White, 1962). This contention was further supported by indirect immunofluorescence assays for SV-5 antigens in BGM/MV cells. No SV-5 antigens were detected when the cells were assayed at various times PS.

Since cells contaminated with mycoplasma have been shown capable of inducing HAD (Berg and Frothingham, 1961), living BGM/MV cells and spent-culture media from two passage levels were submitted to Flow Laboratories (Rockville, MD) for mycoplasma analysis. No mycoplasma were detected using the agar plate and Hoechst staining method.

The age of the indicator erythrocytes used in HAD assays is important for specificity. Dowdle and Robinson (1966) reported non-viral mediated HAD of guinea pig erythrocytes to confluent monolayers of primary Rhesus monkey kidney cells when using erythrocytes stored for more than 72 hrs at 4° C in PBS. In our studies the

Table 1. Adsorption of erythrocytes to BGM/MV and BGM cells

	PERCENT HAD			
ERYTHROCYTES	BGM/MV		BGM	
	24 HRS	96 HRS	24 HRS	96 HRS
Rhesus Monkey	>99	<1	60	15
Human Grp. O	45	<1	<1	15
Guinea Pig	<1	<1	<1	<1
Chicken	<1	<1	30	90
Rabbit	<1	<1	40	90

Table 2. Induction of HAD activity in BGM/MV cells by fetal calf serum[a]

PERCENT FETAL CALF SERUM (VOL/VOL)	PERCENT HAD
0	<1
5	10
10	30
15	60
20	90

[a]Replicate confluent monolayers of BGM/MV cells were treated with various concentrations of fetal calf serum (vol/vol) in growth medium for 24 hours at 37° C and an HAD assay employing Rhesus monkey erythrocytes was performed on replicates of three cell monolayers per fetal calf serum concentration. Each value represents the mean percent HAD activity. HAD values at each fetal calf serum concentration varied <5%.

adsorption of Rhesus monkey erythrocytes occurred using freshly acquired blood and decreased as a function of increasing BGM/MV cell number using the same lots of erythrocytes.

Experiments were performed to further substantiate that the non-measles virus mediated adsorption of Rhesus monkey erythrocytes to BGM/MV cells was related to a phase of cellular metabolism not associated with the resting cell. To this end, confluent BGM/MV cell monolayers were treated with varying amounts of FCS, a complex biological material known to stimulate cell division in resting confluent monolayers of contact-inhibited cells (Temin, et al., 1972). Treatment of confluent monolayers of HAD-negative BGM/MV cells with EMEM suplemented with varying amounts of FCS for 24 hrs at 37° C resulted in increased HAD of Rhesus monkey erythrocytes relative to the amount of FCS present (Table 2). The FCS-induced HAD activity was similar to the cell density-dependent HAD activity in that it could not be blocked by monkey anti-measles virus serum and the percent of cells with plasma membrane-associated measles virus antigens did not increase when the cells were analyzed by membrane immunofluorescence assay.

DISCUSSION

While several other reports of non-viral mediated HAD activity have been published (Franks et al., 1963; Kano and Milgrom, 1965; Neuman and Tytell, 1965) the present report is the first documenting a cell density-dependent, HAD.

Characterization of the cell density-dependent HAD manifested by BGM/MV cells indicated that it was not due to measles virus hemagglutinin or to contamination of the cells with SV-5 or mycoplasma. These observations suggested that the receptor(s) mediating the attachment of the Rhesus monkey erythrocytes is coded for by a cellular gene(s) and are further supported by the observation that the parent uninfected cell line, BGM, also adsorbed Rhesus monkey erythrocytes in an apparent cell density-dependent fashion. Also, BGM/MV cells adsorb human group-O erythrocytes in a cell density-dependent fashion, cells not capable of interacting with measles virus hemagglutinin (Waterson, 1965).

A dose-response relationship was shown between FCS concentration and the percent induction of HAD in confluent monolayers of HAD-negative BGM/MV cells. This relationship and the sustained HAD activity in BGM/MV cells maintained at 33° C, relative to cells maintained at 37° C, suggest that the spontaneous HAD of Rhesus monkey erythrocytes is related to some phase(s) of active cell replication and not solely to cell density.

The expression of specific cell surface antigens and receptors as a function of certain phases of the cell growth cycle have been reported by others. Thomas (1971) found that the expression of B and H blood group antigens on the surface of cultured mouse P815Y cells was cyclic in nature. Resting cells were negative for the B antigen and positive for the H antigen, while actively replicating cells were B antigen positive and negative for the H antigen. It was also found that phytohemagglutinin stimulation of mouse (BALB/C) lymphocytes resuted in the expression of the B antigen.

The agglutination of normal 3T3 mouse fibroblasts by concanavalin A was found to be cell cycle-dependent by Collard et al. (1975) and to occur only in cell mitosis. The agglutination of synchronized cultures of transformed 3T3 cells, however, was maximum in G1 and in mitosis.

Our experience with the BGM/MV cell line suggests that HAD, especially if present in cell lines persistently-infected with virus, should be confirmed as viral specific by serological assay. Two types of HAD of Rhesus monkey erythrocytes have been observed in BGM/MV cells: 1) HAD activity which can be serologically shown to be measles virus-specific (Menna et al., 1975a; Flanagan and Menna, 1976; May and Menna, 1979); and 2) an inherent HAD activity which is non-measles in nature and is apparently associated with the cell-growth cycle.

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CLASSIFICATION AND PROTECTION STATUS OF REMNANT NATURAL PLANT COMMUNITIES IN ARKANSAS

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ABSTRACT

A classification and inventory of Arkansas's remaining tracts of relatively undisturbed vegetation was initiated in 1979. Based on extensive literature surveys and field work, the classification includes five physiognomic classes, 17 cover classes, and 46 cover types, arranged hierarchically. High quality examples of ten of the cover types have been located in designated wilderness or state natural areas, where they are protected by law, while an additional three occur in research natural areas or Forest Service special interest areas. The remaining 33 cover types have no known long-term protection. Lands having wilderness, state natural area, research natural area, or special management area status total nearly 51,000 acres in the state. No more than one-tenth of this area, however, supports vegetation in relatively undisturbed condition.

INTRODUCTION

Natural, relatively undisturbed plant communities are invaluable for a number of reasons. They serve as control areas or "bench marks" for ascertaining natural rates of nutrient cycling, productivity, and soil erosion; as storehouses of information concerning species interactions; as genetic reservoirs for commercially valuable and presently unutilized plants and animals; as testing grounds for basic ecological laws and principles; and in many other ways not easily duplicated elsewhere (Franklin and Trappe, 1968; Moir, 1972; and Jenkins, 1976).

While preservation of outstanding natural areas has long been a primary goal of many organizations and agencies, it was not until recently that such efforts were directed more towards the entire spectrum of natural diversity than just to those species or communities having obvious appeal (Humke et al., 1975). Within this spectrum of natural diversity, some components—such as immature shortleaf pine and oak-hickory forests—are so well-represented on the landscape that special protection efforts are not warranted, while others—including unplowed prairies and old-growth forests—have been so diminished that complete elimination of some types is a possibility. Setting aside high quality examples of these more threatened types is currently of high priority to The Nature Conservancy, state natural area programs, and others.

Efforts to preserve selected natural plant communities have been underway in Arkansas for more than 20 years, dating to the establishment of Big Lake Research Natural Area in 1959. Only two programs, however, have emphasized community preservation *per se*, the natural area program of the Arkansas Natural Heritage Commission and the research natural area program of the federal government. Nonetheless, portions of Arkansas's statutory wilderness areas, scenic and special interest areas, and certain private lands also provide some protection for high quality natural plant communities.

Heretofore, no comprehensive assessment of the types of natural communities protected on such areas has been available, nor has there been any information regarding types lacking protection. The classification system and analysis of protection status presented here represent an attempt to address these needs.

METHODS AND MATERIALS

A thorough search of the literature pertaining to the natural vegetation of Arkansas and adjacent states was completed in 1979. An initial working classification was prepared by listing and comparing the vegetations reported or likely to occur in the state. Field surveys were then undertaken to validate actual occurrence of these types in Arkansas and to collect basic stand data.

One hundred and twenty leads to putatively little-disturbed or otherwise exemplary plant communities were located and surveyed in two field seasons. Communities were surveyed in each of the natural divisions of Arkansas and in two-thirds of the counties. Standardized data collection included estimation of canopy cover by each species (Daubenmire, 1968), determination of degree and types of disturbance, and estimation of the extent of each plant community. Where feasible, canopy cover was estimated within a square, 400 m^2 plot placed within a representative portion of the community, being careful to avoid crossing obvious environmental discontinuities. In many cases, particularly where a tree canopy was monospecific or nearly so, the cover type (defined below) could be determined by simple inspection and the canopy cover estimated over the stand as a whole. In these cases, and where physical conditions were prohibitive, sample plots were not employed.

Stands were considered of high quality and worthy of protection on the basis of several criteria: Forests with no extensive timber removal in the last 60 years, no extensive grazing, no open growth form trees, and predominance of long-lived tree species; and prairies with no plowing, overgrazing, and herbicidal treatment. Other types of vegetation were judged on the basis of relative amounts of various kinds of disturbance. In instances where all known examples of a vegetation type had been fairly recently disturbed, the least disturbed stands were regarded as worthy of preservation.

All stands considered of high quality were classified according to the scheme explained below. Stand data were entered into the files of the Arkansas Natural Heritage Inventory Program.

RESULTS

Classification.

Attempts to provide a statewide listing or classification of major vegetations in Arkansas were made previously by Turner (1937) and Foti (1974). A number of other publications, including Putnam and Bull (1932), Society of American Foresters (1954), Clark (1974), Dale and Kuroda (1978), and Bedinger (1979), provide classifications of the vegetation of particular regions or habitats within Arkansas. These studies were drawn upon extensively in developing the current classification system.

This system places emphasis upon vegetation types represented on the landscape by old-growth, little-disturbed, or "virgin" stands, and by certain other rare or previously little-known types; as such, it

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focuses attention on the kinds of vegetation most in jeopardy in the state. This bias notwithstanding, the system can probably be used for a variety of purposes.

Vegetal-environmental units of varying degrees of specificity may be recognized on the landscape. The natural vegetation over much of Arkansas, for instance, is "forest." But a particular stand in Newton County might be described as a "beech-umbrella magnolia-yellow mandarin community type." A total of four levels of specificity were identified and incorporated in the classification system. This hierarchical system progresses from physiognomic and cover classes, at the most general levels, to both cover and community types.

Physiognomic classes are defined in terms of predominant life forms and general appearance. Classes found in Arkansas include Forest, Savanna, and Herbaceous Vegetation (Table 1). Cover classes are based on dominant genera in the tallest layer of vegetation and a certain range of site conditions. As shown in Table 1, 17 such units are presently in use. Cover types are generally named according to species which recur under similar environmental conditions and which make up 20% or more of the total canopy of a given stand. This category has proven particularly useful for the Inventory Program and will be discussed in detail.

While dominance is a primary criterion for identifying and naming cover types, overemphasis of this factor easily results in a meaningless proliferation of "types" due more to accidents of dispersal or disturbance than to intrinsic site conditions. Therefore, a certain amount of variability among stands within a cover type was considered acceptable even if nominate species was rather poorly represented. Emphasis was on species assemblages tending to recur in similar environments, not on species differences considered in isolation from the environment.

In some cases, dominance was abandoned almost entirely as a basis for discriminating cover types from one another; for example, where the physical environment all but overshadowed the biological, as in rock outcrop communities (e.g., the "sandstone outcrop cover type"). This rule also applied when important regional differences in species composition did not necessarily involve dominants, as in the example of "Osage Prairie."

Of the 46 cover types listed in Table 1, at least 15 represent parts of the potential natural vegetation of the Ozark Mountain and Ouachita Mountain Natural Divisions (natural divisions follow Foti, 1974). Five occur, or potentially occur, on Crowley's Ridge; at least 19 are to be expected in the Mississippi Alluvial Plain; and 25-30 belong in the West Gulf Coastal Plain. Each of these cover types is defined in cover type "abstracts" on file in the offices of the Arkansas Natural Heritage Commission.

Protection Status.

Published information regarding vegetation of natural area quality

Table 1. Outline of vegetation classification system developed for the Arkansas Natural Heritage Inventory Program.*

FOREST VEGETATION	
Quercus Xerophytic Cover Class	
Q. stellata-Q. marilandica	post oak-blackjack oak
Quercus-Carya Cover Class	
Q. alba	white oak
Q. alba-Q. falcata-Carya spp.	white oak-southern red oak-hickory
Q. alba-Q. rubra-Carya spp.	white oak-northern red oak-hickory
Q. rubra-Liquidambar styraciflua-Carya spp.	northern red oak-sweetgum-hickory
Q. velutina-Carya texana	black oak-black hickory
Quercus spp.-*Acer saccharum*	mixed oak-sugar maple
Q. falcata var *pagodifolia-Q. michauxii-Carya* spp.	cherrybark oak-swamp chestnut oak-hickory
Quercus-Pinus Cover Class	
Quercus spp.-*P. taeda*	mixed oak-loblolly pine
Q. alba-P. echinata	white oak-shortleaf pine
Q. stellata-P. echinata	post oak-shortleaf pine
P. echinata	shortleaf pine
P. echinata-P. taeda	shortleaf pine-loblolly pine
Fagus-Mixed Hardwoods Cover Class	
F. grandifolia-Liriodendron tulipifera-Quercus spp.	beech-yellow poplar-oak-hickory
F. grandifolia-Quercus spp.-*Magnolia tripetala*	beech-mixed oak-umbrella magnolia
F. grandifolia-Terrace Hardwoods	beech-terrace hardwoods
Nyssa-Taxodium Cover Class	
T. distichum	baldcypress
T. distichum-N. aquatica	baldcypress-water tupelo
N. aquatica	water tupelo
Quercus Hydrophytic Cover Class	
Q. lyrata-Carya aquatica	overcup oak-water hickory
Q. nuttallii-Q. phellos-Liquidambar styraciflua	Nuttall's oak-willow oak-sweetgum
Q. phellos-Ulmus crassifolia	willow oak-cedar elm
Q. nigra-Liquidambar styraciflua	water oak-sweetgum
Mixed Hydrophytic Oaks	mixed hydrophytic oaks
Populus-Salix-Betula-Platanus-Acer Cover Class	
Populus deltoides	cottonwood
B. nigra-Platanus occidentalis	river birch-sycamore
S. nigra	black willow
A. saccharinum	silver maple
GLADE/OUTCROP VEGETATION	
Xerophytic Hardwood-*Juniperus* Cover Class	
Quercus durandii-Juniperus spp.	Durand's oak-juniper
Q. arkansana-Q. incana-Q. stellata var. *margaretta*	Arkansas oak-bluejack oak-margaretta oak
Juniperus ashei	Ashe juniper
Juniperus virginiana	eastern red cedar
Mixed xerophytic hardwoods	—
Rock Outcrop Cover Class	
Sandstone Outcrop	—
Limestone/Dolomite Outcrop	—
Igneous Rock Outcrop	—
HERBACEOUS VEGETATION	
Andropogon-Sorghastrum-Panicum Cover Class	
Cherokee Prairie	—
Grand Prairie	—
Osage Prairie	—
Schizachyrium-Tripsacum Cover Class	
Blackland Prairie	—
Arundinaria Cover Class	
A. gigantea	giant cane
Emergent Wetland Cover Class	
Typha latifolia	cat tail
Mixed sedge-rush	—
Decodon verticillatus	swamp loosestrife
Aquatic Bed Cover Class	
SCRUB/SHRUB VEGETATION	
Broad-leaved Scrub/Shrub Wetland Cover Class	
Acer rubrum-mixed sedge	red maple-mixed sedge
Quercus Cover Class	
SAVANNA VEGETATION	
Pinus-Quercus-Graminoid Perennial Cover Class	
P. echinata-Q. stellata-Graminoid	shortleaf pine-post oak-grass

*cover types are listed within each cover class; community types have been ommitted

found in Arkansas is scanty (Shepard and Boggess, undated; Waggoner, 1975; Federal Committee on Ecological Reserves, 1977; Zachry et al., 1979) and rarely provides sufficient information to permit classification at the cover type level. Agency reports and site surveys completed before 1979 are of similar value. Hence, most of the findings presented here are field surveys by the author.

Of the more than 34 million acres in Arkansas, about 34,000 acres, or 0.1% of the state, have been permanently set aside to preserve natural features and qualities. In some cases, these include little-disturbed plant communities. The latter, however, occupy no more than 10% of the total "protected area." Most of the 34,000 acres fall within three statutory wilderness areas; the remainder, within the state's 23 natural areas.

High quality examples of ten cover types, one of which occurs twice, are represented for these areas (Table 2). Six of the nine areas, which include seven of the ten cover types, are within the Arkansas System of Natural Areas; the other three areas, each with one cover type, are part of the National Wilderness Preservation System. Although most of the vegetation remnants in these areas are quite small (15-200 acres each), those remnants in wilderness areas eventually may develop into very extensive "old-growth" stands.

Somewhat surprisingly, more permanently protected examples of cover types occur in the Mississippi Alluvial Plain than in any other natural division. On Crowley's Ridge and in the West Gulf Coastal Plain, on the other hand, no mature stands of natural vegetation are protected by law. One high quality example of a cover type is protected in the Ouachita Mountains, and five such examples are protected in the Ozark Mountains.

Several other pieces of public land have also been withdrawn from resource extraction and development activities, though not necessarily on as permanent a basis. These administrative withdrawals usually are made in recognition of outstanding natural, scenic, or geological features. Included are research natural areas, special interest areas, wilderness study areas, and national natural landmarks. Only the first two, however, will be discussed here.

Arkansas has five research natural areas (RNAs), four of which support outstanding examples of little-disturbed plant communities (Table 3). A candidate research natural area on Crowley's Ridge also contains a high quality forest remnant. Two of the cover types found on RNAs are not represented by high quality stands in either wilderness areas or state natural areas, according to available information, while the remaining types listed in Table 3 are so-represented in these areas. RNAs in the state range from 100 to 973 acres and are managed solely for the purpose of non-destructive research. Three of the five RNAs occur in the Ouachita Mountain Natural Division.

No RNAs have been established in the Ozarks, but the Ozark-St. Francis National Forest has recognized 12 areas, ranging from 220 to 7000 acres—for scenic, botanical, and geological features of special interest. These special management units are administratively excluded from most timber management activities, and certain kinds of recreational activities are discouraged as well. Five of these areas, four of which are in the Ozarks, include remnants of mature forest vegetation in excellent condition (Table 4). All but one of the cover types represented, however, are also found in state natural areas or wilderness areas.

In the Ouachita National Forest, the three "scenic areas" not associated with a research natural area total about 920 acres. No significant remnants of mature vegetation have been located on these lands.

In all, nearly 51,000 acres of public lands in Arkansas have wilderness area, state natural area, research natural area, or special interest area status (Table 5). A total of 13 cover types, several represented at least twice, have been located on these lands. Six cover types are protected on more than one site, but seven are found on only one site each and often occupy only a very small area. No cover types are protected on more than four sites, and those occurring on three or four such sites generally exhibit sufficient intra-type variability to justify some seemingly "redundant" protection. Understories of beech forests in the Ozarks, for instance, differ markedly from the ones in the Ouachitas.

Many other high quality examples of natural vegetation, including ones occurring in certain state parks, state wildlife management areas, Forest Service recreation areas, and roadless and undeveloped area evaluation II (RARE II) areas, currently lack any form of long-term protection. Many of the most significant remnants of natural vegetation in the state also occur on private land, but, to date, very

Table 2. Cover types represented on sites protected by law.

Natural Division	Site	Owner	Cover Type
Ozark Mountains	Upper Buffalo Wilderness	U.S.A.	*Fagus grandifolia-Quercus* spp.-*Magnolia tripetala*
	Sweden Creek Falls*	State of Arkansas	*Quercus rubra-Liquidambar styraciflua-Carya* spp.
	Devil's Knob/ Backbone*	State of Arkansas	*Juniperus ashei*
			Sandstone outcrop
			Hardwood glade
Ouachita Mountains	Caney Creek Wilderness	U.S.A.	*Quercus* spp.-*Pinus echinata*
Mississippi Alluvial Plain	Big Lake Wilderness	U.S.A.	*Taxodium distichum*
	Striplin Woods*	U.S.A.	*Quercus lyrata-Carya aquatica*
	Smoke Hole*	State of Arkansas	*Nyssa aquatica*
	Roth Prairie*	State of Arkansas	Grand Prairie
	Konecny Prairie*	Private	Grand Prairie

*in State System of Natural Areas

Table 3. Cover types represented on research natural areas (RNAs)

Natural Division	Site	Cover type
Ouachita Mountains	Lake Winona RNA	*Quercus* spp.-*Pinus echinata*
	Roaring Branch RNA	*Quercus* spp.-*Pinus echinata*
Mississippi Alluvial Plain	Big Lake RNA	*Taxodium distichum*
	White River Sugarberry RNA	*Quercus nuttallii-Quercus phellos-Liquidambar styraciflua*

Table 4. Cover types represented in Forest Service Special Interest Areas

Natural Division	Site	Cover type
Ozark Mountains	Devil's Canyon	*Quercus rubra-Liquidambar styraciflua-Carya* spp.
		Quercus alba-Quercus rubra-Carya spp.
	Dismal Hollow	*Fagus grandifolia*-Mixed Oak-*Magnolia tripetala*
	Sandstone Hollow	*Quercus alba-Quercus rubra-Carya* spp.
	Clifty Canyon	*Quercus alba-Quercus rubra-Carya* spp.
Crowley's Ridge	Turkey Ridge	*Fagus grandifolia-Liriodendron tulipifera-Quercus* spp.

Table 5. Arkansas public lands on which natural vegetation is legally or administratively protected from commercial use or development.*

	Units	Acreage	Fraction of State Total
Wilderness Areas	3	27,575	.0008
State Natural Areas	23	4,023	.0001
Research Natural Areas	6	2,143	.0001
Special Interest Areas	14	16,799	.0005
Totals	46	50,540	.0014

*Sources: Federal Committee on Ecological Reserves (1977), U.S.D.A. Forest Service (1977, 1978a, 1978b), Big Lake National Wildlife Refuge master plan (undated pamphlet), Arkansas Natural Heritage Commission files.

few individuals or corporations have set aside remnant natural vegetation on these lands. One important exception is the old-growth loblolly pine-shortleaf pine stand within Levi-Wilcoxon Demonstration Forest in Ashley County, which has apparently been permanently removed from commercial timber management. Other highly significant natural areas which may be managed to sustain their pristine qualities by the present landowner(s) cannot be regarded as permanently protected.

DISCUSSION

Relatively few of the cover types found in Arkansas are represented by high quality examples in existing wilderness, natural, and special interest areas. In the Ozarks, only mesic oak-hickory and mixed mesophytic types are well-represented, while dry to xeric vegetation has been all but ignored. The Mississippi Alluvial Plain has some fine stands of bald cypress, native prairie, and bottomland hardwood on protected areas, but several bottomland and nonforested wetland types are completely unprotected. The Ouachita Mountains have three protected areas in which high quality communities occur, but the same cover type predominates on each. In the West Gulf Coastal Plain, no mature, little-disturbed plant communities of any kind have been protected and, unfortunately, very few examples of such communities remain. The same could be said for Crowley's Ridge except for the presence there of a single, semi-protected remnant plant community.

Of the 33 unprotected cover types, good examples of all but seven were located during the 1979 and 1980 field seasons. Reflecting the extreme vulnerability of high quality stands, two of the most significant areas—each of which supports two or more cover types—were heavily cut-over during this period. Opportunities to protect outstanding examples of vegetation cover types certainly remain. Accomplishing this goal, however, will require a concerted effort to establish additional research natural areas and wilderness areas, to acquire conservation easements on certain privately-owned lands, and to inform landowners of the irreplaceable nature of the little-disturbed plant communities which remain.

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PRELIMINARY REPORT ON THE FISHES OF THE UPPER SALINE RIVER, POLK AND HOWARD COUNTIES, ARKANSAS, AND OBSERVATIONS ON THEIR RELATIONSHIPS WITH LAND USE AND PHYSICOCHEMICAL CONDITIONS

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ABSTRACT

The Saline River of southwest Arkansas was impounded by Dierks Lake in 1975. Intensive collecting efforts were made in the river system above Dierks Lake during March, April, and May 1980. Collected specimens were compared with ichthyofaunal lists prior to impoundment. Historic occurrants which were not collected include *Notropis amnis, Notropis ortenburgeri, Moxostoma duquesnei, Ammocrypta vivax,* and *Percina copelandi.* Additions to the ichthyofaunal list for the drainage include *Fundulus notatus, Etheostoma spectabile,* and *Percina caprodes.* The evidence indicates that 33 species representing six families inhabit the system from the headwaters in Polk County, Arkansas, to Dierks Lake, Howard County, Arkansas. Erosion within the basin ranges from 956 kilograms per hectare per year on grassland to 158,263 kilograms per kilometer per year on roadbanks. Excessive levels of fecal coliform bacteria, cadmium, copper, lead, zinc, and sulfates were noted within the system. The relationship of these factors to the ichthyofauna is discussed.

INTRODUCTION

Studies involving the fishes of the Saline River are limited, confined to several early studies (Meek, 1891; Hubbs and Ortenburger, 1929; Black, 1940) and those summarized by Buchanan (1973). Collections made during this study expand the ichthyofaunal list for the upper Saline River.

The upper Saline River drains approximately 293 km^2 in northern Howard County and extreme southern Polk County, Arkansas. The stream flows approximately 21 km from the headwaters in the Ouachita National Forest near Shady Lake Recreational Area to Dierks Lake, 8 km northwest of Dierks, Arkansas. Storage began in Dierks Lake 8 May 1975. Stream flow is continuous within the system ranging from about 0.06 m^3/sec in late summer-early fall to 34 m^3/sec in the spring (USGS, 1975-1979).

The basin involves 25,923 hectares and is characterized by narrow, winding ridgetops, rolling to steep wooded mountainsides and narrow stream valleys. Sherwood-Pickens soil associations cover the area and are composed of well-drained Sherwood soils (44%), excessively-drained Pickens soils (25%) and rockland (31%). Slopes range from 8 to 50%, and the depth to sandstone or shale bedrock is 13-23 cm in many areas. Due to severe erosion hazards and coarse fragments which make tillage difficult, this association is not well suited to farming. The area is best suited to woodland, and forests cover 90-95% of the area (Hoelschler et al., 1975).

Physicochemical conditions within the system are fairly typical of Ouachita Mountain streams. The water is soft, containing 26-100 ppm dissolved solids, and the stream is classified as a calcium-bicarbonate type (Rainwater, 1962). Dissolved oxygen concentrations range from summer lows around 4 mg/1 to winter highs around 12 mg/1. Alkalinity values range between 8 and 26 mg/1 ($CaCO_3$). Turbidity levels are typically low, 12-155 JTU, but high runoff periods in spring and winter produce short-term peak loads above 350 JTU (USGS, 1975-1979). Temperatures range from 2-20°C (mean 16°C) in the stream.

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METHODS AND MATERIALS

Thirty-seven fish samples were taken in the system during March, April, and May 1980. Eleven stations on the upper Saline River and two headwater streams (stations 1-4) were sampled (Fig. 1). Standard minnow seines, 3.0, 4.6, and 6.1m in length, and 1.2m in depth were used for sampling. Station locations were: station 1-T4S R28W sect. 30, Polk Co.; station 2-T4S R28W sect. 30, Polk Co.; station 3-T4S R28W sect. 29, Polk Co.; station 4-T4S R28W sect. 29, Polk Co.; station 5-T4S R28W sect. 31, Howard Co.; station 6-T5S R28W sect. 8, Howard Co.; station 7-T5S R28W sect. 16, Howard Co.; station 8-T5S R28W sect. 33, Howard Co.; station 9-T6S R28W sect. 5, Howard Co.; station 10-T6S R29W sect. 25, Howard Co.; station 11-T6S R29W sect. 33, Howard Co.

Spot water quality samples were taken during April sampling periods using a Hach DR-EL/2 portable laboratory. Additional water quality data were provided by the U. S. Geological Survey, Little Rock, Arkansas, for water years 1975-79.

Land use data were provided by the U. S. Soil Conservation Service. These data were collected during a nationwide Resource Inventory Data System (RIDS) effort in association with the Soil and Water Resource Conservation Act (RCA) of 1977, PL 95-192 (Evans, 1981). Erosion rates were calculated by IBM360 computer and are similar to rates obtainable using the Universal Soil Loss Equation (USLE) developed by the U. S. Department of Agriculture.

All specimens collected were preserved in 10% formalin for 2-5 days, washed, and stored in 40% isopropanol. Specimens are stored in the Arkansas State University Museum (ASUMZ) and the U. S. Courthouse, Nashville, Tennessee. All of them eventually will be maintained in the ASUMZ collection.

RESULTS

Thirty-three species of fishes representing six families were either collected during this study or reported by previous authors. An annotated list of these species follows. Nomenclature follows Bailey et al., (1970). Station numbers of collection sites follow the species

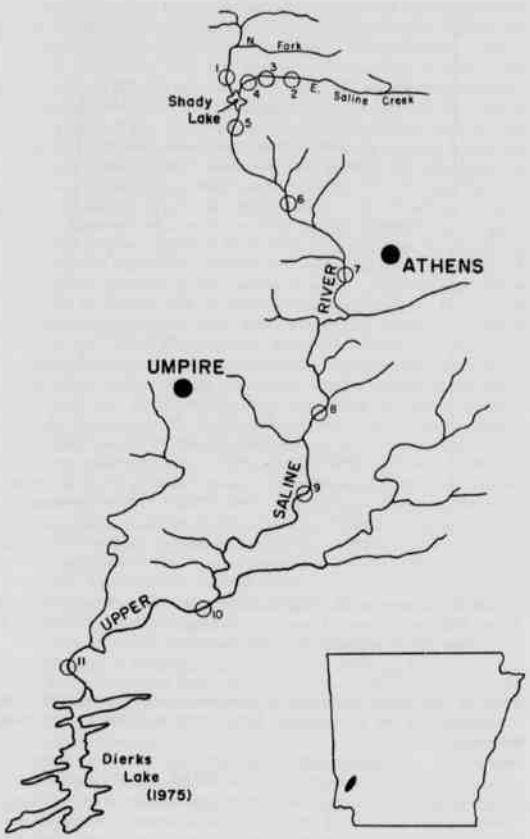

Figure 1. The upper Saline River watershed, Polk and Howard Counties, Arkansas, and collecting stations used in this study.

names and, with notations, provide a brief description of relative abundance.

ANNOTATED LIST OF SPECIES COLLECTED

CYPRINIDAE

Campostoma anomalum (Rafinesque) - Stoneroller- 5,6,7,8,9,10.
Fairly common in middle reaches below Shady Lake.

Notropis amnis Hubbs and Greene - Pallid shiner- not collected.
Extremely rare or absent. Historically occurs in extreme headwater regions.

Notropis atherinoides Rafinesque - Emerald shiner- 6,7,8.
Fairly common in upper reaches below Shady Lake.

Notropis boops Gilbert - Bigeye shiner- 2,3,5,6,7,8,9,10,11.
Common. Most common minnow, collected throughout.

Notropis chrysocephalus (Rafinesque) - Striped shiner- 3,5,6,7,8,9,10,11.
Common. Collected throughout.

Notropis ortenburgeri Hubbs - Kiamichi shiner- not collected.
Extremely rare or absent. Historically occurs in headwater pools commonly with large rocks.

Notropis umbratilis (Girard) - Redfin shiner- 7,8,9,10.
Common in middle reaches usually in pools over sand or gravel bottoms.

Notropis whipplei (Girard) - Steelcolor shiner- 7,8,9.
Common in middle reaches.

Pimephales notatus (Rafinesque) - Bluntnose minnow- 9,10,11.
Fairly common in lower reaches in pools and slower current.

Pimephales tenellus (Girard) - Slim minnow- 10,11.
Rare in lower reaches, taken in water over 2' in depth and in small numbers.

Pimephales vigilax (Baird and Girard) - Bullhead minnow- 9,10,11.
Common in lower reaches over sand or silt bottoms.

Semotilus atromaculatus (Mitchell) - Creek chub- 1,4.
Rare. Collected only in the extreme upper reaches in tributaries above Shady Lake.

CATOSTOMIDAE

Erimyzon oblongus (Mitchell) - Creek chubsucker- 9,10,11.
Fairly common in lower reaches in slow current or pools with detritus deposits.

Moxostoma duquesnei (LeSueur) - Black redhorse- not collected.
Extremely rare or absent. Historically occurs in lower reaches over sand or gravel bottoms.

Moxostoma erythrurum (Rafinesque) - Golden redhorse- 11.
Rare, taken only in extreme lower reaches and in small numbers.

ICTALURIDAE

Ictalurus natalis (LeSueur) - Yellow bullhead- 7,8,9,10.
Fairly common in middle reaches in pools and slow currents over all bottom types.

Noturus nocturnus Jorden and Gilbert - Freckled madtom- 9,10,11.
Rare in lower reaches over sand, gravel, or silt bottoms with detritus deposits.

ATHERINIDAE

Labidesthes sicculus (Cope) - Brook silverside- 9,10,11.
Common in lower reaches over sand, gravel, or silt bottoms.

Menidia audens Hay - Mississippi silverside- 10.
Rare in lower reaches over bottoms with detritus deposits.

CYPRINODONTIDAE

Fundulus catenatus (Storer) - Northern studfish- 9,10.
Extremely rare. Historically occurs in shallow pools and backwaters. Only two specimens collected.

Fundulus notatus (Rafinesque) - Blackstripe topminnow- 9,10.
Rare in lower reaches, in or near pools or elbows.

Fundulus olivaceus (Storer) - Blackspotted topminnow- 8,9,10,11.
Common in the lower reaches in slower current and often with *F. notatus*.

CENTRARCHIDAE

Lepomis cyanellus Rafinesque - Green sunfish- 4,5,6,7,8,9,10,11.
Common throughout in all habitat types.

Lepomis macrochirus Rafinesque - Bluegill- 3,4,5,6,7,8,9,10.
Common throughout in all habitat types.

Lepomis megalotis (Rafinesque) - Longear sunfish- 3,4,5,6,7.
Fairly common in upper reaches, usually in pools over rock bottoms.

Micropterus dolomieui Lacepede - Smallmouth bass- 6,7,8,9,10.
Fairly common in all reaches except extreme upper reaches above Shady Lake.

Micropterus salmoides (Lacepede) - Largemouth bass- 11.
Rare, occurring only at most extreme lower station possibly as migrants from Dierks Lake.

PERCIDAE

Ammocrypta vivax Hay - Scaly sand darter- not collected.
Extremely rare or absent. Historically occurs in lower reaches over sand bottoms.

Etheostoma radiosum (Hubbs and Black) - Orangebelly darter- 2,3,5,6,7,8,9,10.
Common in all but extreme upper and lower stations. Not collected above Shady Lake.

Etheostoma spectabile (Agassiz) - Orangethroat darter- 5,6,9,10.
Fairly common in middle reaches over gravel bottoms.

Etheostoma whipplei (Girard) - Redfin darter- 5,6,7,8,9,10.
Common below Shady Lake over sand or gravel bottoms.

Percina caprodes (Rafinesque) - Logperch- 8,9,10,11.
Common in lower reaches typically in slower currents and commonly associated with detritus deposits.

Percina copelandi (Jordan) - Channel darter- not collected.
Extremely rare or absent. Historically occurs in lower reaches typically over sand, occasionally gravel bottoms.

Water quality data indicate that 5 parameters exceed recommended criteria for support of aquatic ecosystems (EPA, 1976; FWPCA, 1968), and a sixth presents a health hazard for bodily contact with the water. A summary of these criteria used to determine acceptable levels appears in Table 1. Data indicate that levels of some toxic heavy metals had increased steadily within the system following the impoundment of the upper Saline River by Dierks Lake (Fig. 2) until 1979, when conditions began to stabilize. Fig. 2 illustrates conditions at the confluence with Dierks Lake.

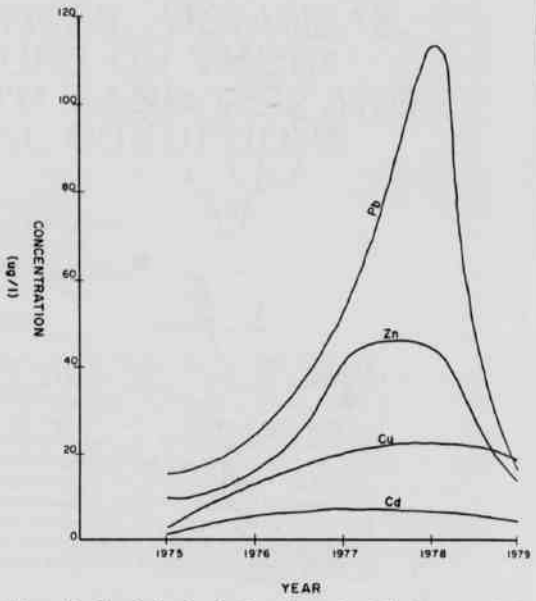

Figure 2. Yearly levels of selected metals within the upper Saline River, Polk and Howard Counties, Arkansas, 1975-1979 (Pb = lead; Zn = zinc; Cu = copper; Cd = cadmium).

Table 1. Levels of water quality parameters requiring concern and criteria used in the upper Saline River, Polk and Howard counties, Arkansas.

PARAMETER	LEVELS OBSERVED (u 1975-79)	ACCEPTABLE LEVEL FOR AQUATIC SYSTEMS	SOURCE OF CRITERION
Fecal Coliform bacteria	506	400[a]	EPA,1976
Turbidity (JTU)	34[b]	50[c]	FWPCA,1968
Alkalinity (mg/l $CaCO_3$)	20.18	20, except where natural state is less	EPA,1976
Chlorine (mg/l Cl)	5.75	10	EPA,1976
Cadmium (ug/l Cd)	4.98	4	EPA,1976
Copper (ug/l Cu)	15.04	5[d]	EPA,1976 Pickering and Henderson,1966
Lead (ug/l Pb)	43.44	2[e]	EPA,1976 Pickering and Henderson,1966
Zinc (ug/l Zn)	25.26	8[e]	EPA,1976 Pickering and Henderson,1966
Sulfate (mg/l SO_4)	18.00	2[f]	EPA,1976

[a]Criterion for bathing. No criterion for aquatic organisms.
[b]Short duration peaks in spring-early summer and winter high water periods may exceed 350 JTU
[c]Standard established by EPA = sufficient turbidity to reduce light penetration by 10%
[d]Based on 0.1×96hr LC_{50} of most sensitive species present as determined by non-aerated bioassay.
[e]Based on 0.01×96hr LC_{50} for most sensitive resident species.
[f]Criterion for undissociated H_2S

RIDS information indicates that silviculture and associated businesses dominate commercial activities within the basin. Forests are approximately 83% loblolly-shortleaf pine. Thirty percent of these are 0-10 years old, 39% are poorly to moderately stocked, and roughly 6% (1234 ha) are disturbed annually. These statistics illustrate the intensification in silvicultural operations within the basin in recent years. Since the banning of 2,4,5-T, several replacement chemicals have been used and tested in these operations within the watershed (Evans, 1981). Examples are Tordon 101 (picloram, 4-Amino-3,5,6-trichloropicolinic acid), Garlon 3A (silvex, 2-[2,4,5-trichlorophenoxy] propionic acid), and 2,4,DP Weedone II (2,4-dichlorophenoxyacetic acid, methyl ester) (ChemService, Inc., 1981). The active ingredient in Tordon 101, picloram, is one of the most effective chemicals available for converting low quality hardwood forests to commercial species (Lawson and Ferguson, 1972). Each liter of Tordon 101 contains 0.06 kg of picloram. Picloram is fairly persistent in forest soils, especially during drought conditions (Neary et al., 1979). Furthermore, picloram adsorption is increased in soils high in organic matter, further slowing leaching processes. In this situation, picloram may remain for several months in the upper 30-60 cm of soil, which becomes soil loss during the erosion process, and may be laden with picloram upon entry into stream systems (Evans and Duseja, 1973). Although not persistent in the aquatic environment, picloram concentrations as low as 35 ug/1 affects yolk sac adsoprtion by fry of some species (Johnson and Finley, 1980). Silvex accumulates in fat, muscle, liver, and kidney tissues in livestock (Menzie, 1980). Toxicity to fish has been reported with concentrations as low as 0.36 mg/1 (Stewart, 1975), and action by a mixed culture of organisms is required to degrade it rapidly in the aquatic environment. Degradation releases chloride and CO_2. Weedone II is not persistent in soils, but may be toxic to fish at concentrations of 4.0 mg/1 (Stewart, 1975).

Land use within the basin has changed very little in the years since impoundment of Dierks Lake. Urban and built-up areas total less than 1%. Predominant land uses are forestland (93%) and grassland (7%). Forested acres have increased by an average of 3% per year since 1975, with a corresponding decrease in grassland acreage. Gross erosion also had increased during this period by 5% per year to the present rate of 2.06×10^8 kg per year, basinwide. Silvicultural activities, particularly forest harvesting operations and road construction, can accelerate transport of soil material downslope by soil mass movement (Overcash and Davidson, 1980). An increase in service roads, spur roads, and skid trails has contributed significantly to the erosion problem within the basin. These roads, totaling 312 km, erode at an average rate of 196,014 kg/km/yr. The accepted criterion for identifying severe conditions is 96,030 kg/km/yr (Evans, 97,812 kg/ha/yr. Unfortunately, as these areas become revegetated, ment resulting from timber harvesting activities (Stone et al., 1978). Other sources accompanying harvest intensification are associated with the heavy machines required to offset a dwindling labor force by allowing a small crew with complimentary machines to cut, process into the desired dimensions, load, and transport the timber at tenfold the rate of hand labor (Saucier, 1980). As a result, acres disturbed by harvesting operations are eroding at a rate in excess of 97,812 kg/ha/yr. Unfortunately, as these areas become revegetated, other problems develop. As sediment is decreased by upland erosion control measures, including reforestation, more energy becomes available for other processes within the stream itself, particularly streambed and bank erosion (Grissinger and McDowell, 1969; McDowell and Grissinger, 1976). A streambank within the basin of 202 km is currently eroding at a rate of 113,457 kg/km/yr. Sediment from these and upland sources damages aquatic environments by scour, burial, and abrasion (Ritchie, 1972). The substrate and associated organisms may be removed, detached, and/or carried away by the erosion process. Photosynthetic and food source organisms may be buried by accumulating sediment or killed by abrasion during the course of sediment movement (Brockway, 1979). Erosion problems within the upper Saline are summarized in Table 2.

Table 2. Average annual gross erosion summary for the upper Saline River watershed, Polk and Howard counties, Arkansas.

SITE	UNIT MEASURE (hectares)	KILOGRAMS PER UNIT MEASURE	TOTAL KILOGRAMS
Grassland	1823	956	1.74×10^6
Forestland	24101	4957[a]	1.19×10^8
	25924		1.22×10^8
	(kilometers)		
Streambank	202	113457	2.29×10^7
Road surfaces	312	37943	1.18×10^7
Roadbanks	312	158263	4.94×10^7
		TOTALS	2.06×10^8

[a]Distributed forestland (u = 1234 ha/yr) erodes at a rate of 97812 kg/ha/yr.

DISCUSSION AND CONCLUSIONS

Factors affecting the fishes and other stream organisms in the upper Saline River are contributing to an overall decline in numbers of species and organisms. Among these factors are excessive metal introduction, excessive erosion and sedimentation, possible herbicide contaminations for short periods, and contamination by agricultural and domestic wastes.

Area fish species which may have been affected by these factors include *N. amnis, N. ortenburgeri, M. duquesnei, A. vivax,* and *P. copelandi.* These species were not collected in this study. Species collected in this study which were not previously reported in the upper Saline River include *F. notatus, E. spectabile,* and *P. caprodes.* Further collecting efforts may reveal additional species.

Land use within the drainage has had a marked effect on the aquatic ecosystems. The pristine conditions normally associated with forested, virtually unsettled drainage basins are disappearing from the upper Saline River drainage due to both intensified use of remaining agricultural lands and conversions of low grade hardwood forests to commercial species. In the former case, small farming operations have been supplemented by poultry production for economic purposes. Most of these farms do not have proper waste management systems or facilities for storing or disposing of dead birds (Evans, 1981). In the latter case, roughly 72% of all timber lands within the basin are owned by a single timber company. Maximum production on these acres has resulted in severe erosion problems from both maintenance of traffic lanes for heavy equipment and annual disturbance of approximately 1234 forested hectares.

Bare rock outcrops, unprotected escarpments, and gravel operations are possible sources for the excessive levels of metals noted in the upper Saline River. Concentration of these substances in Dierks Lake since impoundment has created conditions unsuitable and often toxic to aquatic life (Table 2 and Fig. 2). Lead, zinc, cadmium, and copper have been found in excessive amounts in Dierks Lake since its creation and are toxic to aquatic organisms. Lead enters the aquatic environment through precipitation, lead dust fallout, erosion and leaching of soil, and other pathways associated with large cities. Zinc usually is found in nature as a sulfide and is often associated with the sulfides of other metals, particularly lead, cadmium, copper, and iron. Cadmium occurs in nature chiefly as a sulfide salt, frequently associated with zinc and lead ores. Accumulations in soils in the vicinity of mines and smelters may cause high level concentrations in nearby waters. Copper occurs as a natural, or native, metal and in various mineral forms such as cuprite and malachite. The most important copper ores are sulfides, oxides, and carbonates (EPA, 1976).

Specific effects of these pollutants on the fishes of the upper Saline River are not quantified herein, however some general conclusions are noted regarding the species considered very rare or not collected during this study. *Notropis amnis* has not been reported in large numbers from any locality within its range (Miller and Robison,

1973), but where found, it tends to avoid swift currents and to intolerate excessive siltation and turbidity. Increases in these latter parameters have contributed to *N. amnis'* showing the most marked decline of any Missouri fish in recent years (Pflieger, 1975). However, historic occurrence of this fish in the study area was in the extreme headwater region, and a more logical explanation for its decline would be the construction of Shady Lake Recreational Area. Similar habitat requirements appear to apply to *N. ortenburgeri*, but specifics of its life history and habits are lacking (Miller and Robison, 1973). *Moxostoma duquesnei* is intolerant of turbidity and pollutants. Young of this species are dependent on stable backwater areas, where they feed on algae and small crustaceans. Siltation is increased in these areas in the upper Saline River as reductions in current allow suspended sediment to settle out. As a result, these habitats and food sources are reduced or absent and young mortality increases. Also, adult habitat preferences, in the lower mainstem, have exposed members of this species to the conditions illustrated in Table 2 and Fig. 2. The northern studfish, *F. catenatus*, is more of a bottom feeder than other topminnows (Pflieger, 1975), taking the majority of its food from silt-free sand, gravel, or rock bottoms (McCaskill et al., 1972). These areas have been drastically reduced by siltation in the upper Saline River. *Percina copelandi* also requires silt-free gravel or rock bottoms in slow mainstem currents. Abundant chironomids, other insect larvae, and microcrustaceans are preferred food sources (Miller and Robison, 1973). Eggs are laid in sand bottoms in the spring and deserted. These requirements are seriously lacking in the upper Saline, and, due to the instability of available sand bottoms in the stream, spawning success may have been affected. The Scaly sand darter, *A. vivax*, will bury in the sand bottoms out of strong current, but it is intolerant of siltation and turbidity (Pflieger, 1975). Exposure of both *P. copelandi* and *A. vivax* to the toxic levels noted in Table 2 and Fig. 2 during the early years of Dierks Lake has probably been a causal factor for their decline (Tarzwell and Henderson, 1960).

Future environmental degradation can be avoided in the basin only if problem areas are addressed in the near future. These areas include the need for proper waste management on existing agricultural lands, roadbank stabilization, erosion control during the harvesting and revegetation operations on forestland, preservation of a riparian vegetation zone as a natural filter strip, and control of runoff from mining and/or gravel operations. The techniques involved and their environmental values have been adequately described by previous authors (Mader et al., 1972; Kochenderfer, 1970; Bednar and Fluke, 1980; Johnson and McCormick, 1978; Stern and Stern, 1980; Newbold et al., 1980).

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DISTRIBUTION OF FENITIZED CRUSTAL XENOLITHS IN CARBONATITE INTRUSIONS, WEST-CENTRAL ARKANSAS

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ABSTRACT

Crustal xenoliths from carbonatite intrusions in the Morrilton-Perryville Arkansas area display a variety of mineralogical and textural features that suggest that they are fragments of basement crystalline rock that has undergone sodic metasomatism resulting from their close proximity at depth to a carbonatite complex. With increasing degrees of fenitization, the leucocratic xenoliths range from granolite - syenite - analcite syenite, while the melanocratic xenoliths range from hornblende - biotite to aegerine-apatite.

A definite increase in fenitization is observed from Morrilton in the north to Brazil Branch, 16.8 km to the south. Fenitized xenoliths from Brazil Branch are generally quite small (0.5 cm - 1.0 cm) and contain a substantial amount of analcite. At Morrilton Lock and Dam, the fenitized xenoliths are very large (1.0 cm - 2.5 cm), and granolites are common. The xenoliths at Oppello Dump are intermediate in both size and mineralogical character. This area is therefore interpreted as a single alkalic - carbonatitic complex at depth, with its center near the southern extremity of the sampled area.

INTRODUCTION

Three carbonatite intrusions from the Morrilton, Oppello, and Perryville areas of west-central Arkansas have been studied to determine distribution of incorporated metamorphic xenoliths (Fig. 1). Previously, Mitchell (1979) studied the xenoliths petrographically and found a suite of rocks ranging progressively from granolites (Winkler, 1976) to analcite urtite-ijolite fenite that have been metasomatically altered. Mineralogical evidence indicates metasomatism at high temperatures and lower crustal pressures. Mitchell (1979) concluded that the metasomatically altered xenoliths result from deep seated fenitization of crustal material by emanations from a carbonatite magma. He also suggested that each intrusion was related to a separate carbonatitic complex at depth. The present study was undertaken to determine the distribution of fenitization in a north-south direction from three of the intrusions. This study proposes that the degree of fenitization of the crustal material increases to the south suggesting a single source of fenitizing emanations.

METHODS OF INVESTIGATION

Samples were collected by Mitchell (1979) at the various carbonatite localities in the study area, but only the xenoliths from the Morrilton sill (Lock and Dam No. 9), Oppello Dump, and Brazil Branch were studied because corresponding thin sections were only available from those localities.

Twenty-eight slabs were cut from samples at Morrilton Lock and Dam, 53 were cut from Oppello Dump, and 96 were cut from Brazil Branch. Fifty thin sections were available from the three localities. Single thin sections were compared petrographically with the appearance of the same xenolith megascopically on the slab to establish criteria for distinguishing the eight lithologies of wall rock alteration.

RECOGNITION OF FENITIZATION STAGES

Granolites exhibit a clear, unturbid appearance, and quartz is easily distinguished. Feldspars are porcelainous white and subhedral

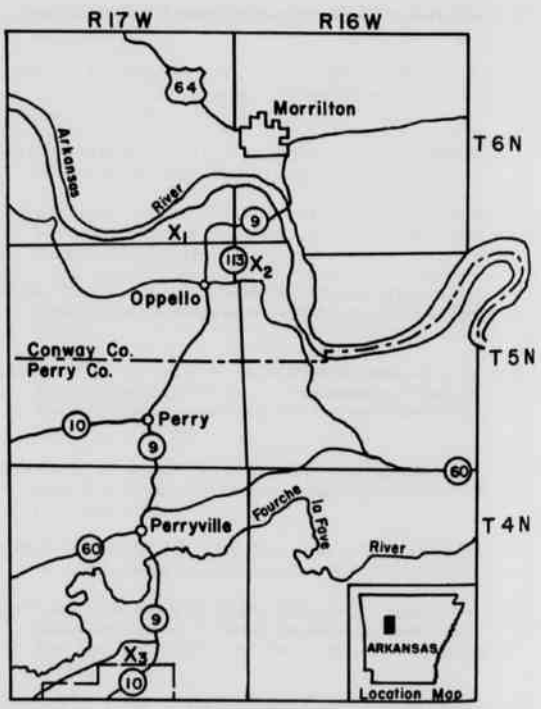

Figure 1. Location of various carbonatite intrusions within study area: X_1 Morrilton Dam Sill; X_2 Oppello Dump; X_3 Brazil Branch Breccia.

with albite twinning on the plagioclase. Mafics compose about 20% of the xenolith and consist of biotite and hornblende. Granolite xenoliths are on the order of 2.0 cm × 2.0 cm.

Quartz Syenite Fenite represents the first stage of alteration in the leucocratic xenoliths. Quartz is granulated due to shock metamorphism. Carbonates replace quartz. Aegerine appears as small green patches that are randomly scattered throughout the xenolith. Feldspars are relatively unturbid.

Syenite Fenite represents the second stage. Quartz has been completely removed. Feldspars become turbid and appear brown. There is a loss of twinning in plagioclase. Aegerine becomes more abundant due to the introduction of sodium.

Albite Syenite Fenite is the third stage in the alteration process. Feldspars are very turbid and indicate a transformation to albite. Aegerine and carbonates are abundant.

The final stage is represented by analcite urtite - ijolite fenite. Isotropic analcite is abundant as a white mineral that has no apparent crystal boundaries. Aegerine becomes dark-green upon the introduction of analcite. These xenoliths are on the order of 1.0 cm × 1.0 cm.

The initial stage at alteration in the melanocratic xenoliths is represented by hornblende - biotite xenoliths. The xenolith is black due to many subhedral crystals of hornblende and biotite. These xenoliths are about 1.0 cm × 1.0 cm.

The second stage of alteration in the melanocratic xenoliths is represented by hornblende - aegerine xenoliths. Aegerine is dominant in these xenoliths. No quartzofeldspathic minerals are present. These xenoliths are about 1.0 cm × 1.0 cm.

The final stage of alteration in the melanocratic xenoliths is represented by aegerine - apatite xenoliths. The xenolith appears dark-green because aegerine comprises about 95% of the material. No quartzofeldspathic minerals are observed. Apatite occurs as small, translucent grains due to the introduction of phosphorus. The xenoliths are about 0.5 cm × 1.0 cm.

REGIONAL RELATIONS

Morrilton Sill (Lock and Dam No. 9).

This sill is exposed on the south flank of the Arkansas River near Lock and Dam No. 9. It is a small sill about 46 cm thick and is intruded into the Atoka Formation of Pennsylvanian age. Abundant fresh metamorphic xenoliths are exposed in the sill, and 28 samples were available for study. The fenitized crustal xenoliths are quite large, significantly larger than those from the other sampled areas. The xenoliths from Morrilton display a wide variety of mineralogy, including abundant quartz, alkali feldspar, plagioclase, biotite, hornblende, aegerine, sodic amphibole, and carbonates.

As shown in the cumulative histogram of the Morrilton Lock and Dam No. 9 locality, the most common rock type is syenite fenite (Fig. 2). There is also an abundance of granolites, most of which are greater than 2.5 cm in diameter. An acid test proved that no analcite is present. The feldspars are all fresh and unalbitized. The xenoliths thus represent minimal metasomatic alteration. Melanocratic xenoliths are rare. Leucocratic xenoliths appear relatively unaltered. Quartz is present as small, equant droplets. Feldspars are fresh and appear porcelainous white. Therefore, the Morrilton sill is interpreted as an area of minor metasomatic alteration.

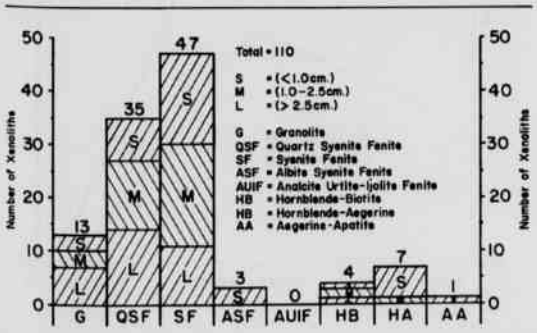

Figure 2. Cumulative histogram for leucocratic and melanocratic xenoliths from Morrilton.

Oppello Dump Sill.

This sill is exposed in a small stream that crosses Arkansas Highway 113, 1.85 km northeast of the community of Oppello. At this exposure, the sill is about 30.5 cm thick and heavily weathered. Actually, the outcrop is in a shale pit previously used as a dump site, hence the name Oppello Dump. The sill is intruded into the Stanley Shale of Mississippian age. Fifty-three samples were available for study. The fenitized crustal xenoliths average 1.5 cm × 2.0 cm. Also incorporated in the carbonatite from Oppello Dump are innumerable sedimentary xenoliths from the Stanley Shale. These sedimentary xenoliths are angular due to their shallow depth of origin. The metamorphic xenoliths exhibit a variety of mineralogies with abundant plagioclase (extensive development of albite), alkali feldspar, sodic amphibole, aegerine, and carbonates.

The cumulative histogram of the Oppello Dump sill shows that the most common rock type is syenite fenite (Fig. 3). However, there is also a great abundance of albite syenite fenite. It would appear that at this locality the xenoliths exhibit more intense metasomatic alteration than those of the Morrilton sill. No granolites were observed at Oppello Dump and also, some analcite is introduced into the more extensively altered xenoliths. The melanocratic xenoliths are quite small, and aegerine dominates the rock. Silicon and potassium have been removed, gradually replaced with calcium and sodium as indicated by the replacement of quartz with calcite and aegerine. Feldspars are turbid and albitized. The Oppello Dump sill is interpreted as an area of moderate metasomatic alteration.

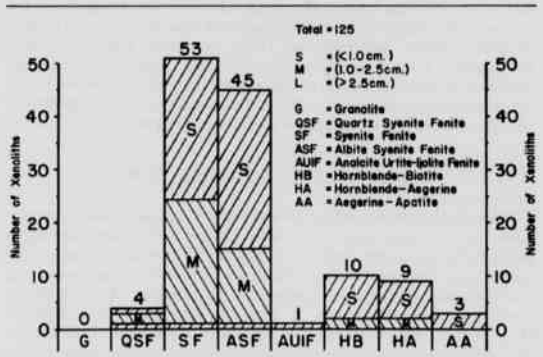

Figure 3. Cumulative histogram for leucocratic and melanocratic xenoliths from Oppello Dump.

Brazil Branch Breccia.

The breccia is exposed approximately 16.8 km south of the Morrilton sill. Mitchell (1979) interpreted this outcrop as a breccia pipe. The outcrop is poorly exposed and somewhat weathered; however, 96 samples were available for study. The fenitized crustal xenoliths from Brazil Branch are, on the average, the smallest of the three sampled areas and average 0.5 cm × 1.0 cm. The mineralogical characteristics of the xenoliths are altogether different from those at

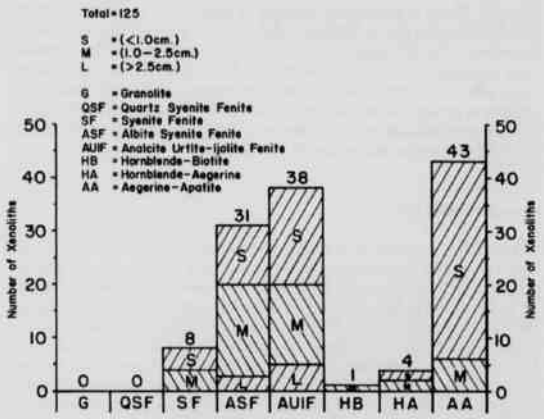

Figure 4. Cumulative histogram for leucocratic and melanocratic xenoliths from Brazil Branch.

Morrilton Lock and Dam No. 9 in that the most abundant minerals are albite, analcite, and aegerine. No quartz was observed, the feldspars are albitized, and in many instances, the feldspars have transformed into analcite. Analcite comprises 60% of the xenolith, in some cases, with dark-green aegerine making up the rest of the xenolith.

The cumulative histogram of Brazil Branch shows that the most common leucocratic rock type is analcite urtite-ijolite fenite (Fig. 4). Albite syenite fenite is also an abundant leucocratic rock type. The very small aegerine-apatite assemblage dominate the melanocratic xenoliths. It appears that this locality is an area of intensive metasomatic alteration. The xenoliths are smaller, and their mineralogy suggests extensive alteration. The presence of analcite suggests that these xenoliths were metasomatically altered at pressures of 6-8 kilobars. At shallower depths, nepheline would have formed instead of analcite (Roux and Hamilton, 1976). The Brazil Branch xenoliths are rounder than those from Oppello Dump and Morrilton. This rounding is due to chemical reaction with the carbonatite and physical abrasion in transport. The Brazil Branch Breccia is interpreted as an area of extensive metasomatic alteration at depth.

VARIATIONS OF XENOLITH TYPES

The cumulative percentage plot of north-south variations of leucocratic xenolith type provides a visual picture of how the rock types are distributed in the study area (Fig. 5). It is evident that as one moves from Morrilton in the north to Brazil Branch in the south, rock type abundance changes according to the intensity of metasomatic alteration. The percentage of granolite decreases from 13% at Morrilton, to 0% at Oppello Dump and Brazil Branch. Conversely, the percentage of analcite urtite-ijolite fenite increases from 0% at Morrilton, to 1% at Oppello Dump, to 50% at Brazil Branch. The distance between Morrilton Lock and Dam No. 9 and Brazil Branch is about 16.8 km,and as one moves toward the south, a definite graduation can be seen. The fenitizing agent of the three localities is sodic in nature, and the source of these fenitizing agents is centered near the Brazil Branch locality.

The cumulative percentage plot of north-south variations of melanocratic xenolith type concurs with this interpretation (Fig. 6). The percentage of hornblende-biotite decreases from 40% at Oppello Dump, to 2% at Brazil Branch. Conversely, the percentage of aegerine-apatite increases from 9% at Oppello Dump, to 90% at Brazil Branch. Toward the southern end of the study area, the intensity of metasomatic alteration is gradually increasing. The study area is interpreted as a single alkalic-carbonatitic complex at depth, with its center near the southern extremity of the sampled area.

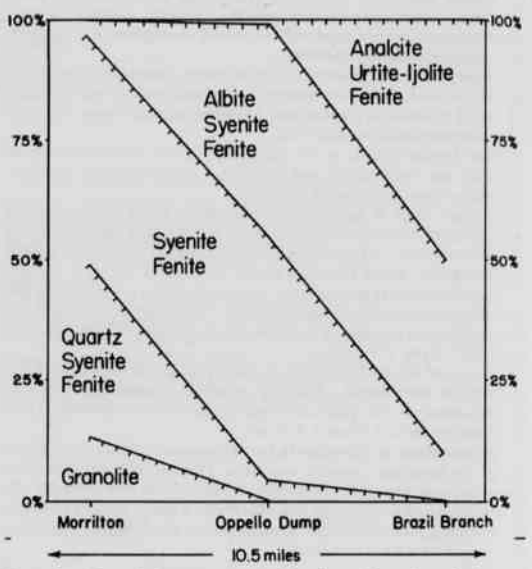

Figure 5. Cumulative percentage plot of north-south variations of leucocratic xenolith type.

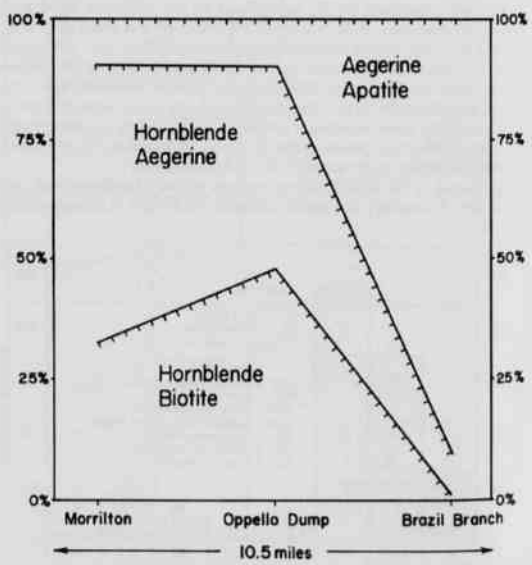

Figure 6. Cumulative percentage plot of north-south variations of melanocratic xenolith type.

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MATURATION, SPAWNING PERIOD, AND FECUNDITY OF THE WHITE CRAPPIE, *POMOXIS ANNULARIS* RAFINESQUE, IN BEAVER RESERVOIR, ARKANSAS

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ABSTRACT

Gonosomatic indices and ovum diameter frequency distributions showed that the Beaver Reservoir white crappie spawns from late April through May. During the spawning season females release eggs more than once. Various stages of ovarian ovum development were described. Sexual maturity was found in 2-year-old females of 197 mm and 3-year-old and older fish. Regression analyses of fecundity on total length, weight and age of white crappie indicated that the fish weight was the best predictor of fecundity.

INTRODUCTION

The white crappie, *Pomoxis annularis,* is an important sport fish in Beaver Reservoir and is second only to largemouth bass, *Micropterus salmoides,* in total pounds harvested (U. S. Fish & Wildlife Service, National Reservoir Research, unpublished data). The reproductive habits of the white crappie have been studied, but information on sexual maturation process and fecundity is meager, especially in the southern states (Morgan, 1954; Whiteside, 1964; Siefert, 1969; Mathur et al., 1979). This paper describes the seasonal changes in ovarian ovum morphology, frequency of spawning, and fecundity of the Beaver Reservoir white crappie.

MATERIALS AND METHODS

A total of 109 female white crappie were collected by angling, rotenone, and electroshocking in 1974 (January - August), 1978 (September - December) and 1979 (January - August). Data on total length (mm) and weight (g) were taken for each fish. Ovaries were preserved in 10% formalin. Fish were aged by the number of annuli on the scales taken from the body beneath the tip of the left pectoral fin.

Monthly gonosomatic index (GSI), the percentage of the fish weight contributed by the ovaries, was estimated for individual fish. The diameters of 200 ova from the midsection of an ovary were measured to the nearest 0.02 mm. The ovarian ovum developmental stages were described on the basis of shape, yolk deposition, and color of the ova. Fecundity, the total number of maturing and mature ova in both the ovaries, was estimated by the wet gravimetric method based on a 5 - 10% ovary sample.

RESULTS

Seasonal Development of Ovaries.

The gonosomatic indices (Fig. 1) increased from September through April. The most rapid rate of development of ovaries occurred from March to April with a drop in GSI in May. The GSI values continued to decrease during June, reaching the lowest point in July or August, depending on the age of the fish. One-year-old crappie showed no increase in the index throughout the year and were presumed immature. The trends in GSI indicated that white crappie spawn from late April through May.

Morphological examination of the ovaries showed an increase in ovary size from December through March. The ovaries of the April specimens were large and full, appearing yellowish in color with the ova visible through the ovarian wall. In May, the ovaries were flaccid, and during June, July and August they were completely flaccid and smaller in size. These changes corresponded with those of the gonosomatic indices. Sixty-five percent of the 2-year-olds (49 fish) had typical seasonal ovary development. The smallest mature 2-year-old female was 197 mm in total length and weighed 84 g. All 3-year-old and older fish were sexually mature.

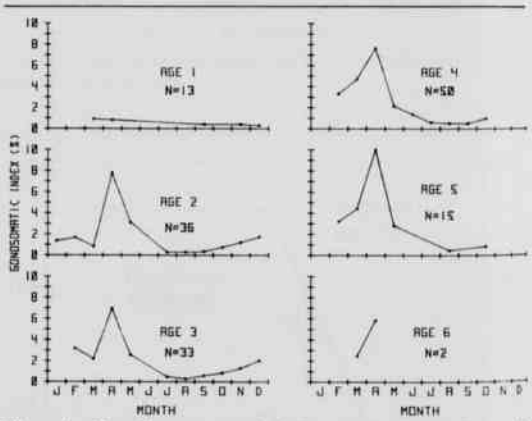

Figure 1. Monthly gonosomatic indices for the Beaver Reservoir white crappie.

Ovum Developmental Stages.

Developmental stages of the white crappie ova are described according to the criteria of James (1946) and Litt (1952). The five stages and ranges of ovum diameters are:

Stage I. Youngest oocytes (Primary ova). 0.02 - 0.16 mm.
These ova were platelike with a distinctly round or oval nucleus (Fig. 2A).

Stage II. Vacuolization of cytoplasm (Immature ova). 0.12 - 0.36 mm.
The ova in this stage were translucent and spherical. Cytoplasm

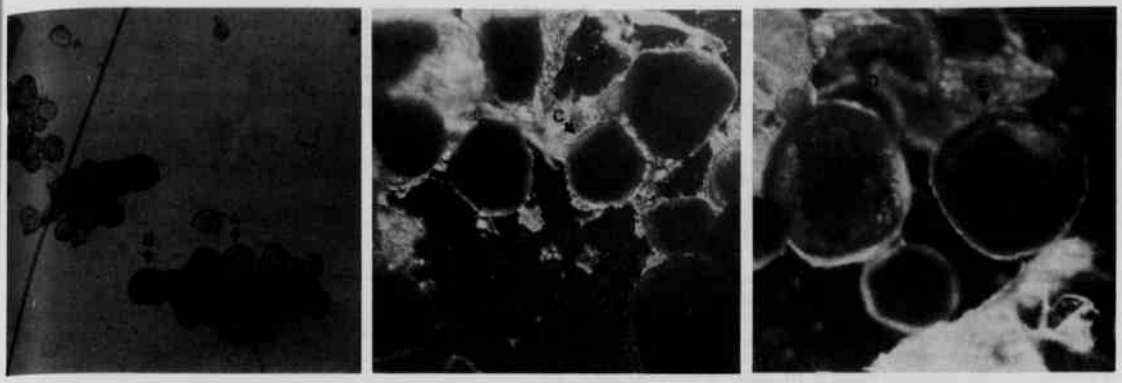

Figure 2. Ovarian ovum developmental stages (100×). A. Stage I B. Stage II C. Stage III D. Stage IV E. Stage V

showed vacuolization and nucleus was visible in some smaller ova. Most ova appeared whitish in color (Fig. 2B).

Stage III. Yolk deposition (Maturing ova). 0.34 - 0.64 mm.
The ova were opaque due to deposition of yolk in the cytoplasmic vacuoles. Nucleus was not visible (Fig. 2C).

Stage IV. Coalescence of yolk globules (Mature ova). 0.58 - 1.02 mm.
The ova were granular due to the presence of large yolk globules. The most advanced mature ova had large oil droplets visible within the cytoplasm. The color of the ova changed from whitish-orange to a yellow or orange (Fig. 2D).

Stage V. Residual ova.
These were the retained ova in the ovary after spawning. In addition to the ova in stages I and II, these spent ovaries had some stage III and IV ova as residuals. Many of the residual ova were in an atretic stage with the cytoplasm appearing to shrink away from the ovum membrane (Fig. 2E).

Ovum Diameter Frequency Distributions.

Six subsamples from the anterior, middle, and posterior parts of both the ovaries of a prespawning fish showed that frequency distributions of the ovum diameters were not significantly different either within an ovary or between the left and right ovaries.

The ovum diameters were pooled for the ages 2 through 6, and the frequency distributions are shown in Figure 3. Stage I ova were present in all ovaries throughout the year. Increase in ovum size to stage II occurred between August and October. The ovaries of November, December, and January contained stage III ova, and some stage IV ova were observed in February and March. The ovaries of April contained ova of all four stages, with ova in stages III and IV forming distinct and dominant modes. In May, large ova in stage IV were absent, indicating the occurrence of spawning. During the first two weeks of May, the ovaries contained large numbers of stage III and IV ova, but their percent frequency was much less than in April. By the end of May, few ova larger than 0.34 mm were observed. In June, although Figure 3 shows small number of ova larger than 0.34 mm, four of the five fish examined had few ova above this size. In July the retained ova larger than 0.34 mm were reabsorbed. The changes in frequency distributions of the ovum diameters indicate that spawning occurs from late April to middle of May and that the remaining stage III and IV ova are extruded by the end of May. It is also evident that white crappie spawn ova that are 0.34 mm and larger in diameter (stages III and IV).

Fecundity Estimates.

Ova in stages III and IV (0.34 - 1.02 mm) were used in fecundity estimates. This parameter was estimated for 16 mature females (GSI = 6.46 - 11.16), of ages 2 through 5 collected in April, that contained full complement of stage IV ova. The estimated fecundity ranged from 48,058 to 232,026 for fish ranging from 217 mm (118 g) to 335 mm (582 g) in size. The relationships between fecundity and total length, weight and age were described by the curvilinear function:

$$F = a X^b$$

where, F = fecundity and X = total length, weight or age.

The estimated parameters are given in Table 1. Based on the coefficients of determination (r^2) and standard error of estimates (S_{yx}), weight of white crappie gives the best estimate of fecundity.

Table 1. Statistics of curvilinear relationship between fecundity and total length, weight, and age of white crappie.

Variable (X)	Intercept (a)	Slope (b)	Coefficient of determination (r^2)	Standard error of estimate (S_{yx})
Total length	4.859×10^{-4}	3.397	0.798	0.091
Weight	631.749	0.897	0.846	0.079
Age	31,650.937	1.128	0.662	0.118

DISCUSSION

Based on gonosomatic indices, gross examination of ovaries and ovum diameter frequency distributions, the spawning period of the Beaver Reservoir white crappie extended from late April through May. In Oklahoma, they spawned in April and May (Whiteside, 1964), during May and June in Illinois (Hansen, 1951), from late May through June in South Dakota (Siefert, 1969), and in Ohio spawning season extended from April into July (Morgan, 1954). The white crappie attained sexual maturity in Beaver Reservoir between two and three years of age, and similar findings were reported by Hansen (1951), Litt (1952), Towery (1963), and Whiteside (1964).

Characterization of ovum developmental stages of the Beaver Reservoir white crappie closely paralleled the stages described by James (1946) and Litt (1952). According to Hansen (1951), Morgan (1954), and Whiteside (1964), the mature ovum size ranged from 0.82 to 0.92 mm. Litt (1952) stated that most of the mature ova (stage IV)

ranged in diameter from 0.42 to 0.67 mm; however, in our study, stage IV ova ranged from 0.58 to 1.02 mm in diameter. Although there is a difference in size range of stage IV ova in these studies, morphological descriptions of these ova were almost identical.

Large numbers of maturing (stage III) and mature (stage IV) ova were observed in ovaries of early May. By late May, few ova in these stages were noted, with only a few of these ova as residuals in June ovaries. By July, all residual ova were reabsorbed. These observations suggest that Beaver Reservoir white crappie do not release all of their stage III and stage IV ova in one spawning act but may extrude over a period of time during the spawning season. Fractional spawning was postulated by Hansen (1951), Morgan (1954), and Whiteside (1964).

Ovum size used in fecundity estimates varied considerably. Morgan (1954) and Whiteside (1964) used mature ova (≥ 0.82 mm) in their estimates of white crappie fecundity. Mathur et al. (1979) determined fecundity based on mature ova (≥ 0.75 mm). Siefert (1969) included secondary oocytes and maturing and mature ova, comparable in morphologic descriptions of stages II, III, and IV ova of our study. Huber and Brinkley (1935) and Towery (1963) reported on fecundity estimates but did not mention the ovum size. We included ova 0.34 mm and larger (stages III and IV) in fecundity estimates. Since fractional (multiple) spawning is indicated and ova above this size were reabsorbed in the postspawning ovaries, it is essential to include more than just the most advanced group of ova in fecundity studies.

Although fecundity estimates were reported in the literature, the relationship between fecundity and length, weight, and age was not determined with the exception of Mathur et al. (1979). Our study and that of Mathur et al. (1979) found that weight was the best predictor of white crappie fecundity.

ACKNOWLEDGMENTS

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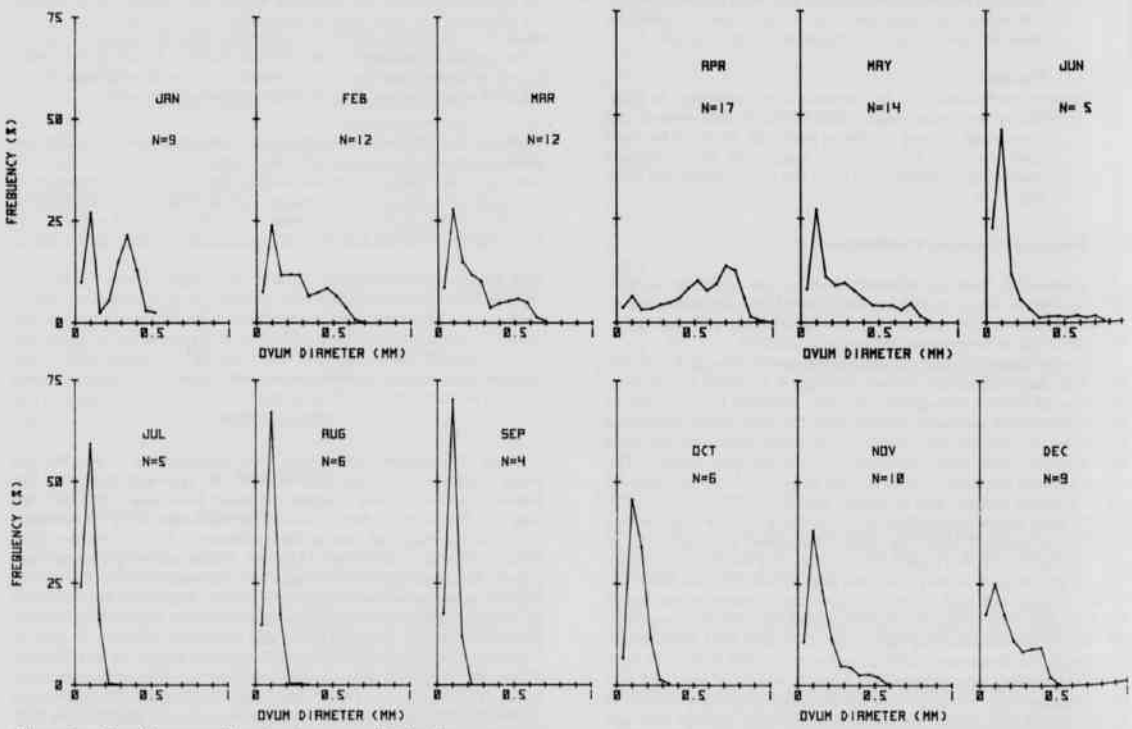

Figure 3. Monthly ovum diameter frequency distributions.

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THE RIVER OTTER IN ARKANSAS: I. DISTRIBUTION AND HARVEST TRENDS

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ABSTRACT

River otter (*Lutra canadensis*) management in Arkansas is hampered by a lack of information on population parameters. This initial study on the biology of Arkansas river otter is concerned with present distribution and harvest trends. Otter occur throughout Arkansas, except in the upper Ozark region. A distributional shift, apparently along the Arkansas River, has led to an increase in otter harvest in the Ouachita Mountain region. A dramatic increase in otter harvest over the past four years (1976-1979) is attributable, in part, to a pelt price increase. Additionally, nuisance level beaver (*Castor canadensis*) populations and an extended trapping season for beaver may have influenced the otter harvest.

INTRODUCTION

The status of the river otter (*Lutra canadensis*) in North America has been of concern in recent years, causing it to be placed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Its status in Arkansas must be determined. Most states contiguous with Arkansas consider the otter to be threatened or rare (Schwartz and Schwartz, 1959; Lowery, 1974; Kennedy and Harvey, no date).

Holder (1951) estimated a population of 700-800 otter in Arkansas, primarily in the Delta region. Harvest records of the Arkansas Game and Fish Commission for the 1979-80 trapping season indicate a take (749 otter) equal to the 1951 population estimate. Sealander (1956) reported that otter were found in over 40 counties in Arkansas, principally in the central and eastern parts of the state. He believed otter populations to be increasing at that time. Sealander and Gipson (1974) placed the otter in the position of "status undetermined". Sealander (1979) included a distribution map for the river otter in Arkansas (based on museum specimens and fur harvest records), and he reemphasized that otter appear to be increasing, parallel to muskrat, beaver, and nutria populations. This paper is concerned with the distribution and possible population trends of river otter in Arkansas as evidenced by museum specimens and fur harvest records.

METHODS AND MATERIALS

Fur harvest records of the Arkansas Game and Fish Commission for the past 20 years (1959-79) were utilized in this investigation. The accuracy of these records affects all subsequent calculations and assumptions concerning them. We tried to discern the relative accuracy of fur harvest records by comparing available harvest data (by county) with the number of furbuyers licensed in each county. Such a comparison should reveal the validity of reports (completed by the furbuyer) concerning the county of origin of otter pelts (it is possible that furbuyers report the county of sale rather than the county of origin).

The Arkansas Game and Fish Commission used the four major physiographic regions of Arkansas (Gulf Coastal Plain, Ouachita Mountains, Ozark Mountains, and Delta) to group otter harvest records. Physiographic bias exists since the county boundaries of Holder (1951) were used to demarcate regions. Foti (1974) has shown that, in fact, eastern White County is deltaic and that the entire southern tier of Ozark counties (according to Holder) actually contain components of both the Ouachita and Ozark physiographic regions.

Since habitat characteristics vary among physiographic regions, certain habitat requirements for otter would more likely be better represented in one region than another. The Delta and Gulf Coastal Plains regions appear to include more of the preferred otter habitat in Arkansas. Harvest records were used to test the hypothesis that, in response to habitat, more otter occur in the Delta and Gulf Coastal Plain and are therefore taken more often from these regions.

Fluctuations in harvest records cannot be interpreted as fluctuations in furbearer populations *a priori*. To facilitate interpretation of harvest records, factors or variables suspected of influencing otter harvest were examined (e.g., otter pelt price and beaver harvest).

RESULTS AND DISCUSSION

In many counties with reportedly high takes of otter there were no licensed furbuyers, whereas few otter were reported from several counties with many furbuyers. Since furbuyers often listed counties other than their own as sources of pelts, harvest data seemed sufficiently accurate to allow analysis of harvest by region.

The reported otter harvest from each physiographic region for trapping seasons from 1959-1979 are shown in Figure 1. The Gulf Coastal Plain generally produced the greatest harvest, with the Delta ranking second in most years. These results support our preliminary hypothesis. However, in the past few trapping seasons, the Ouachita Mountain region became more important as a source of otter pelts, and in the 1979-80 season surpassed the Delta. For the Ouachita region, the otter harvest from 1976 to 1979 comprised 89.1% of the total Ouachita otter harvest since 1959. In the Gulf Coastal Plain, this same four-year harvest period represented 50.3% of the total, for the Delta 48.9% and for the Ozarks 75.4%. Incomplete harvest records for the 1980-81 season indicate that the trend is continuing.

This trend could be explained by a combination of factors. Increased agricultural activities and channelization projects in the Delta would logically be detrimental to otter habitat, and therefore to populations. If heavy harvest in early years reduced otter populations (Sealander, 1979), then more controlled harvest in recent years may have allowed a return of river otter to the Ouachita region. Additionally, the recent population explosion of beaver may have promoted otter re-establisment by creating suitable habitat via the damming of smaller streams.

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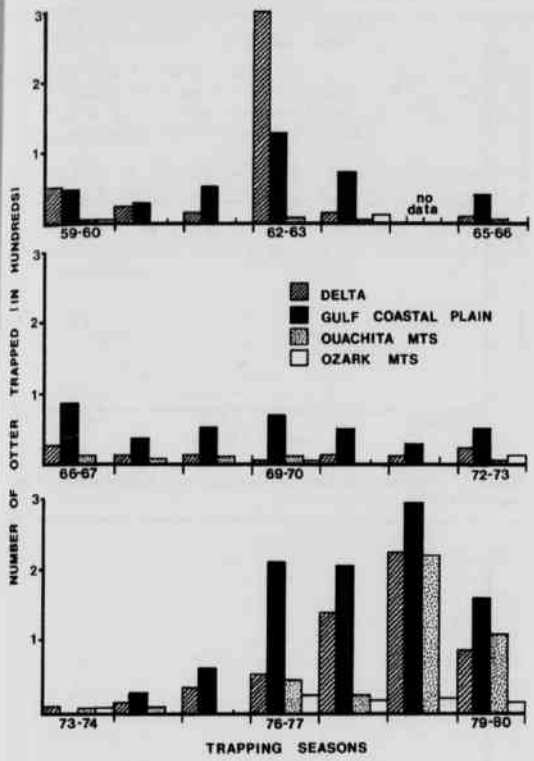

Figure 1. Reported otter harvest by physiographic region for trapping seasons from 1959-1979.

Major drainages used by otter throughout Arkansas include the Arkansas, White, Black, Saint Francis, L' Anguille, Cache, Ouachita, Saline, Little Missouri, and Red rivers. Also, major creeks and bayous are utilized, and the collective range and state of alteration (e.g., impoundments and channelization) of these waterways determine otter distribution, since the species is adapted to an aquatic environment.

Our proposed recent distribution of the river otter in Arkansas is indicated by stippling in Figure 2. Records show the heaviest harvest to be in central and southern Arkansas, from Perry to White counties in the Ouachitas, through Woodruff, Monroe, Prairie, and Arkansas counties in the Delta, down to Grant, Clark, Ouachita, and Calhoun counties in the Gulf Coastal Plain. Ozark counties collectively tally one to 35 pelts per year, and the counties from which they come vary from year to year. Harvest from Delta counties bordering the Mississippi River likewise yield few otter pelts. In recent years, otter distribution apparently has shifted to include more of the Ouachitas than has been previously reported (Sealander, 1979). This is possibly due to dispersal along the Arkansas River system, since the counties bordering the river yield more pelts. Other Ouachita counties, e.g., Polk, Scott, and Montgomery, report only a few otter pelts which, again, vary from year to year with regard to county of origin. Circles in extreme northwestern Arkansas (Fig. 2) represent reports by Sealander (1956, 1979) of an otter killed in 1948 and of sight records of Dellinger and Black (1940). Recently, two otter were taken from Madison County (1977-78 season). The current status of the otter in the extreme northwestern part of Arkansas is uncertain. Consequently, the older records have been excluded from the map of the recent distribution of Arkansas otter.

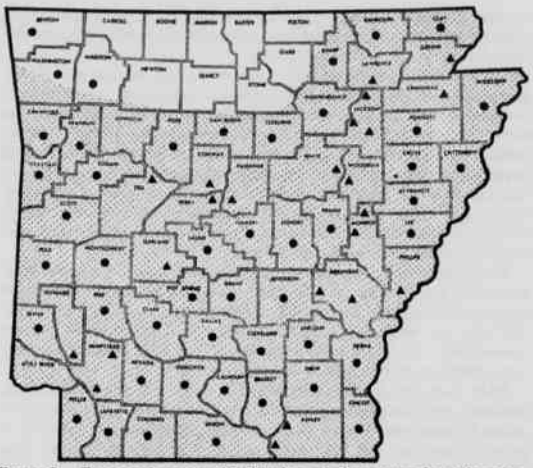

Figure 2. Proposed recent distribution of river otter in Arkansas. Triangles represent specimens from the Collection of Recent Mammals, Arkansas State University Museum of Zoology (ASUMZ). Circles appear in counties not represented in the ASUMZ collection but for which fur harvest records or literature citations are available.

Otter harvests have ranged from 25 pelts (1973-74 season) to 749 (1978-79 season). Although the reported take dropped to 400 in 1979-80, incomplete tabulations for the 1980-81 season indicate a minimum take of 650 otter. A plot of otter harvest versus otter pelt price was subjected to linear regression analysis. Pelt price has risen concurrently with the post-1976 harvest increase. The regression line has a positive slope (b=2.44), representing 2.44 more otter being taken for each dollar increment in fur value. The positive correlation coefficient for these data (0.729) suggests that the increase in harvest is at least partially attributable to pelt price increase. Values of otter pelts over this time period ranged from $11.00 (1967-68) to $43.97 (1978-79). Otter pelt prices have remained consistently high as compared with those of other furbearers.

Fluctuations in otter harvest may be artifacts of harvest records or may represent actual population trends. In an attempt to interpret fluctuations in otter harvest data, a means of viewing otter harvest in light of "trapping pressure" was sought. Otter harvest was compared with a potential indicator of trapping pressure (inherent in the fur harvest records). Total harvest is not a valid indicator as it represents a composite of 14 to 15 species having variable harvest parameters. This melange of species variables must be reduced to one variable representative of a hypothetical "constant trapping pressure". Qualifications of this "indicator species" are:

1) it must compose a significant part of the total harvest,
2) it must have peaks and crashes of harvest similar to the total harvest (i.e., it must represent a constant percentage of the total harvest),
3) it must not be uncharacteristically affected by increases or decreases in pelt price, and
4) it must be found in habitats similar to those of the otter, thereby being subject to similar trapping strategies (i.e., it must be a wetland furbearer).

The mink (*Mustela vison*) most closely meets these prerequisites in Arkansas. Annual mink harvest is compared with total harvest in Fig. 3. During most of the time frame, mink obviously "track" the total harvest, and normally represent from 6-11% (average of 8%) of the

harvest. Price for mink has always been relatively high ($4.00-$14.00, averaging $7.80) and reasonably constant. Mink are also wetland furbearers, meeting the fourth criterion.

Figure 4 depicts mink and otter harvest for the 20 year period. Because so few otter historically have been taken, their numbers have been multiplied by a factor of 10 to facilitate comparisons on the same graph with mink. In some years, such as the 1970-71 season, mink drop but otter do not decrease proportionately, although total harvest and mink harvest exhibit similar crashes. To explore the relationship between otter and mink harvests, the number of otter harvested per mink was plotted for each trapping season (Fig. 5). Seasons from 1969-71 showed an increase in the number of otter taken per mink, as did the 1978-79 season.

The peak in 1970 was a function of the mink harvest. At that time, both mink harvest and mink fur price were at a minimum. Otter were low in price compared to most years but were above their minimum; the take was down but not substantially so. The low mink harvest caused the otter/mink ratio to increase. The 1970 peak, then, does not represent an otter population increase.

Price seems to have had its effect in 1978. As otter price nearly doubled, the take of otter pelts also nearly doubled. Mink were more valuable than ever before, but take did not follow the increase in price. Therefore, the 1978 peak in Fig. 5 is the result of an otter harvest increase, most likely in response to otter pelt price.

Beaver *(Castor canadensis)* harvest has risen greatly statewide due to increases in both beaver population and trapping for beaver control. This higher take is not a function of pelt price, which remains relatively low, but it could be a significant factor in increasing otter harvest. Beaver may be trapped legally for a much longer season than otter. Presently, beaver are considered to be at nuisance level and therefore are trapped for control as well as for fur. Beaver sets are normally kill sets, and otter accidentally caught in them are killed, thereby artificially extending the otter trapping season. Usually these otter are frozen and sold during the next legal furbearer season, elevating otter harvest levels following periods of intensive beaver trapping.

CONCLUSIONS

Otter harvest has increased substantially over the past 20 years, most notably since 1976, but whether or not it reflects a real population increase is still uncertain. Much of this increase can be attributed to a higher otter pelt price, and consequently selective trapping pressure, and also to more beaver trapping. Too, it may be a function of increased otter populations, but this possibility is not confirmed in fur harvest records. These variables, such as pelt price, inherent in harvest records, obscure true population increases. Ironically, increased otter harvest may have, in a sense, "masked" elevated population levels. Without knowledge of the true population increase, if it indeed exists, increased harvest could easily exceed the harvest tolerance of the otter population. Investigation of the biology of Arkansas river otter continues, to gain further insight into its true status in Arkansas.

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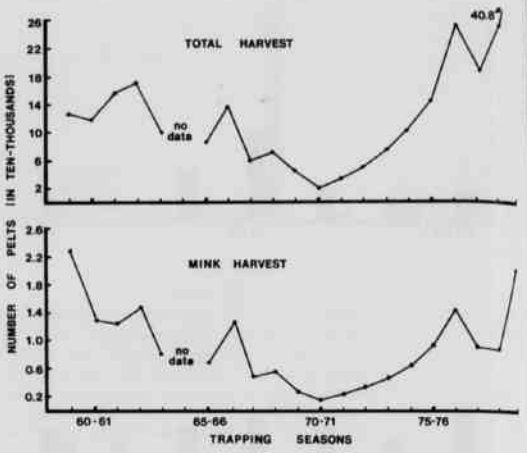

Figure 3. Annual mink harvest compared with total annual fur harvest (1959-1979).

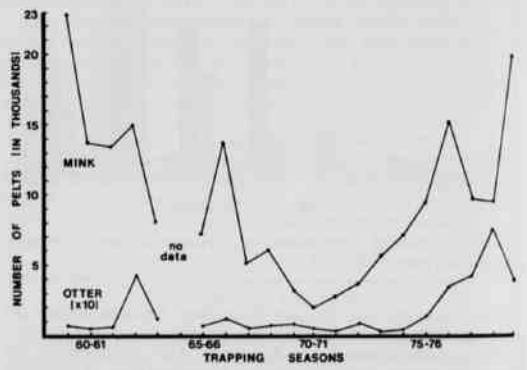

Figure 4. Mink harvest compared with otter harvest (1959-1979). Otter numbers have been multiplied by a factor of 10 to facilitate comparison.

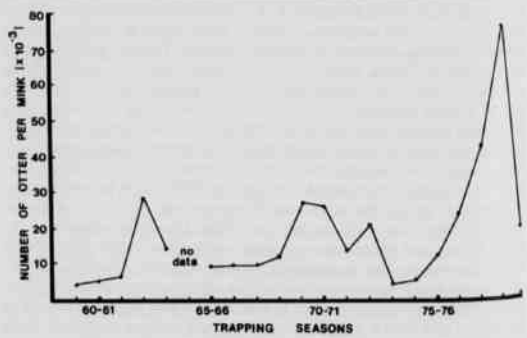

Figure 5. Ratio of otter harvest to mink harvest (1959-1979).

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FLUOROGRAPHIC TECHNIQUE FOR DETECTING AND RECORDING CHLOROPHYLL AND ITS DERIVATIVES ON PAPER AND THIN-LAYER CHROMATOGRAMS

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ABSTRACT

Light from a blacklight lamp (General Electric BLB) is restricted to a waveband range 360 - 470 nm by cut-off filters consisting of 4 cm 1 M aqueous $CuSO_4$ and acrylic plastic sheets. This filtered lamp emission is used to excite the characteristic red fluorescence of chlorophyll and its derivatives on paper or thin-layer chromatograms. Fluorescent spots are detected and recorded by exposure of red-sensitive panchromatic photographic printing paper (Kodak Panalure) to the fluorescing chromatogram. A thin yellow filter interposed between the chromatogram and the photoprint paper restricts the detected fluorescence to wavelengths greater than about 500 nm. Standard development of the photoprint yields grey to black spots on a white background. Intensity and size of the recorded spot is proportional to the amount of a single chlorophyll derivative on the chromatogram over a limited range of pigment applied to the chromatogram. A one-minute exposure with filtered light from an 8 watt GE BLB lamp at a 10-cm distance will record 0.3 nanomole (270 nanogram) chlorophyll *a* on Whatman No. 1 or on Whatman 3 MM paper chromatograms. Detection of chlorophyll derivatives by this technique is at least 10-fold more sensitive than visualization of the pigment spots on the chromatograms by their green color. This fluorographic technique can be a useful adjunct to chromatographic analyses of porphyrins in general.

INTRODUCTION

Chlorophylls and other porphyrin derivatives emit characteristic orange to deep red fluorescence when irradiated with ultraviolet (UV) light or with blue-violet light. This fluorescence allows visual detection of these substances on paper or thin-layer (TL) chromatograms with greater sensitivity than visualization of the pigment spots by their reflected colors in white light (Falk, 1964; Šesták, 1963). Depending on the color of the compound and the background, spots containing a few micrograms of some porphyrins are visible by reflected light. However, with fluorescence using 365 nm excitation, detection can be increased 100-fold, and with special fluorescent enhancement techniques as little as 0.005 μg of some porphyrins can be detected on paper chromatograms (Blumer, 1956).

Location of fluorescent spots on chromatograms can be recorded by outlining the spots while the chromatogram is viewed under UV illumination (Udenfriend, 1962) or by photography (Jackson, 1965; Milton, 1962; Sievers and Hynninen, 1977). Many of the chlorophyll derivatives are unstable under such conditions, i.e. UV light adsorption causes bleaching apparently via photo-oxidation processes (Falk, 1964). Thus, recording of fluorescent spots of chlorophyll derivatives on paper or TL chromatograms requiring prolonged or repetitive exposure to UV light may lead to incomplete registering because of spot disappearance.

Contact-photoprinting of fluorescence from paper chromatograms was first reported for recording nucleic acid spots (Markham and Smith, 1949). By flooding the developed chromatogram with a fluorescent compound, the UV-adsorbing nucleic acid spots appeared as dark areas on a fluorescing background when the chromatogram was viewed under UV (265 nm) light. When a contact photoprint was made of the fluorescing chromatogram, nucleic acids were recorded as white spots on a dark background. Abelson (1960) developed a contact printing process for recording fluorescent spots of paper chromatograms directly. This technique involves use of a near-UV light source (ca. 365 nm) for excitation. The fluorescence exposes a sheet of Kodabromide printing paper. A Kodak Wratten 2A filter interposed between the chromatogram and the photographic paper prevents spurious UV light from being recorded. Modifications of these basic fluorographic techniques have been used to record several different kinds of fluorescent substances or UV-absorbing substances on chromatograms (e.g., Abelson and Rosenfeld, 1962; Bush, 1952; Jones, 1965). However, application of fluorographic techniques for recording spots of porphyrin derivatives, in particular chlorophyll derivatives, has yet to be reported.

A fluorographic method based generally on the technique of Abelson (1960) has been developed for chlorophyll and its derivatives. Fluorescence of the pigment spots is excited with blue-violet light and is then recorded by contact printing on photographic printing paper having a panchromatic emulsion.

METHODS AND MATERIALS

Fluorographic Apparatus and Technique.

Arrangement of components in the apparatus is depicted in Figure 1. The excitation light source for fluorescence is an 8 watt blacklight lamp with an integral filter (General Electric BLB lamp) which emits light maximally ca. 365 nm. This light source emits UV which causes significant, rapid bleaching of chlorophyll derivative spots on chromatograms. The destructive UV wavelengths shorter than 350 nm are removed by inclusion of three 2.5 mm-thick acrylic plastic sheets (Flex-O-Glaze; Warp Brothers, Chicago, IL) in the light path. This filter system yields uniform 65% transmittance from 400 to 800 nm with less than 2% transmittance at wavelengths less than 350 nm. A liquid filter of 1 M aqueous $CuSO_4$ is also required to eliminate the small amount of lamp-emitted red light which causes fogging of the photographic paper during exposure. Although the container for the liquid filter shown in Figure 1 was a Pyrex glass tray, a container can also be made from acrylic plastic to combine the two kinds of cut-off filters that must be used with the blacklight source. The emission of this filtered light source, calculated from the transmission curves of the filter systems and from the spectral emission curve for a GE BLB lamp (Jackson, 1965) has the major emission band from 360 to 470

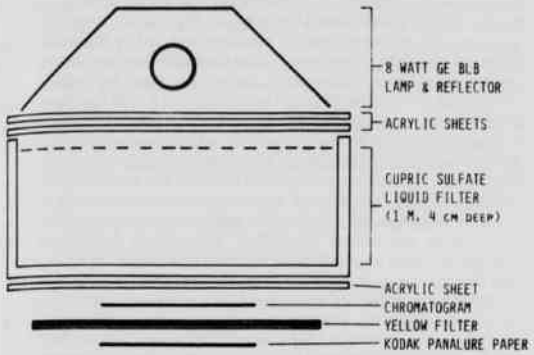

Figure 1. Arrangement of light source, filters, chromatogram, and photographic paper during fluorography.

nm with a peak near 390 nm. A secondary filter interposed between the chromatogram and the photographic paper is used to restrict the fluorescence detected by the photographic paper to wavelengths greater than ca. 520 nm. Any yellow or orange filter materials can be used, provided they transmit strongly from 550 to 750 nm but have less than 1% transmittance from 350 to 480 nm. A useful secondary filter is composed of four layers of commercial yellow cellophane sandwiched between 5 mil-thick, rigid plastic sheets. It is important that this secondary filter be as thin as possible for maximum fluorescence detection and minimum spot magnification during exposure of the photographic paper. Transmission characteristics of all the filters in the system were determined by measurement with a Perkin-Elmer model 202 spectrophotometer.

The critical element in the fluorographic apparatus is the panchromatic photographic paper which must be sensitive to light in the range 600 to 750 nm where prophyrin derivatives fluoresce (Falk, 1965). Kodak Panalure photographic printing paper has a spectral sensitivity from 400 to 680 nm (Eastman Kodak Co., personal communication). It is readily obtained and is sensitive to chlorophyll *a* fluorescence.

The blacklight lamp with reflector and excitation light filter system are mounted in a box that has a stop-aperature to minimize internal light scattering. A sliding panel in the light path is located below the liquid filter and above the chromatogram and is used as a shutter for controlled exposure periods. Before exposure, the yellow filter is placed over a sheet of photoprinting paper, and the developed chromatogram is placed over the yellow filter. With TL chromatograms having sucrose or cellulose adsorbent layers, the adsorbent surface of the developed chromatogram is covered with a protective 1 mil polyethylene film before placement, adsorbent surface down, on the yellow filter. Thus, the excitation light passes through the glass support of the chromatogram, and the fluorescing spots are close to the photographic emulsion. The chromatogram is held in close contact with the yellow filter and photographic paper by a piece of plate glass or in a photographic enlarging easel. This assembly is inserted into the box along guides which provide precise registry of the chromatogram in the light field at a 10-cm distance from the lamp. The operation must be conducted in a darkroom illuminated only with dim yellow-green or amber safelight because of the broad spectral sensitivity of the Kodak Panalure paper emulsion. Exposure times of 45 to 90 seconds are routinely used. Chromatograms on Whatman No. 1 paper require generally shorter exposures, while Whatman 3 MM and sucrose TL chromatograms require longer exposures for similar spot recording. The exposed photographic paper is then developed as recommended by the manufacturer.

Preparation of Chlorophyll Pigment Solutions.

To demonstrate the effectiveness of the fluorographic technique in analysis for pigment purity, fresh and aged extracts of henbit (*Lamium amplexicaule* L.) leaves were chromatographed, then fluorographed. One leaf sample was extracted by maceration with 80% aqueous acetone, then the brei was centrifuged free of debris. This extract solution was aged by exposure to room light and air for 5 hrs before chromatographic analysis. A second leaf sample was similarly extracted, but the extract was chromatographed within 15 min after extraction. Equivalent amounts of the two extracts (measured on the basis of their light absorption at 665 nm via spectrophotometry) were applied to the same chromatogram.

Sensitivity of detection by the fluorographic method was tested by chromatographing a mixture of chlorophyll *a* and pheophytin *a*. For this test, a chromatographically-pure mixture of the pigments from leaves of mung bean (*Vigna radiata* [L.] Wilczek) was prepared as follows: an acetone extract of the tissue was mixed with petroleum ether; the pigments were transferred into the ether layer by addition of water; the epiphase was partitioned with an equal volume of 90% aqueous methanol to extract the xanthophylls; then the epiphasic petroleum ether solution was chromatographed on a column of powdered sugar according to Smith and Benitez (1955). After development, the blue-green zone and part of the more mobile grey-green zone were removed from the column, and the pigments were eluted from the adsorbent with diethyl ether. The absorption spectrum of this solution was measured, and the amounts of chlorophyll *a* and pheophytin *a* were calculated from the absorbance values at 410 nm and 430 nm and the molar absorptivities of these pigments (Smith and Benitez, 1955). The molar ratio of chlorophyll *a* to pheophytin *a* in the solution was 1.8:1. Amounts of total pigment from 0.5 to 5.0 nmol (0.29 to 2.9 μg and 0.16 to 1.6 μg of chlorophyll *a* and pheophytin *a*, respectively) were applied to the chromatogram.

Paper Chromatography.

Pigment solutions were applied as spots near one end of 5 × 17 cm sheets of Whatman No. 1 or Whatman 3 MM chromatography paper. Pigment applications were limited to minimize overloading of the chromatograms (Strain, Sherma, and Grandoflo, 1968). Ascending development of the chromatograms with mixtures of acetone, benzene, and petroleum ether (b.p. 60-100 C) gave resolution of the chlorophyll derivatives as distinct spots within a solvent migration of ca. 13 cm which required 25 to 30 min at room temperature. All solvents were reagent grade. Routinely, a developing solvent of acetone-benzene-petroleum ether, 1:5:5 (v/v), gave sufficient resolution of the chlorophyll derivatives, and the spots remained stable for several exposures to light during fluorography. Solvent systems containing more polar components, e.g. 1-propanol, contributed to the rapid bleaching of some of the red-fluorescing spots during fluorography. All manipulations for developing and preparing the chromatogram for fluorography were conducted in dim room light or darkness to minimize degradation of the pigments. The developed chromatograms were air-dried before fluorography. No special techniques were used to enhance the fluorescence of spots on the chromatogram. When needed for future reference, the origin line and solvent front line on the developed chromatogram were marked with a small spot of 0.3% (w/v) aqueous Eosin Y solution near each end of the lines. Fluorescence of the dye in the spots was recorded during fluorography and allowed precise orientation of the chromatogram and fluorogram during subsequent analysis.

RESULTS AND DISCUSSION

The fluorographic technique reported here, in combination with paper and TL chromatographic analyses, has been useful for assessing the purity of chlorophyll derivatives, for estimating the extent of pigment degradation in leaf extracts and chlorophyll preparations,

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and for detecting unsuspected chlorophyll derivatives in certain pigment preparations. These aspects are illustrated in the fluorograms shown in Figure 2.

Figure 2A shows a fluorogram of the simultaneous chromatographic analysis of two extracts of *Lamium* leaves. Chromatographic separation of pigments in the fresh extract (Fig. 2A.i.) shows the presence of chlorophylls *a* and *b* and some pheophytin *a* (near the solvent front). Similar analysis of the pigments in an extract that was exposed to room light and air for 5 hrs before chromatography (Fig. 2B.ii.) shows the effect of destructive "aging" on the chlorophyll pigments; more pheophytin *a* was present, as well as two additional red-fluorescing pigments near the origin. Based on R_f characteristics in the chromatographic system used, the pigment at the origin was probably "oxidized chlorophyll" and that of $R_f = 0.07$ was probably chlorophyllide *a* which was produced by enzyme-catalyzed hydrolytic cleavage of the phytyl group from the chlorophyll *a*. The spots of both these low R_f compounds could not be detected on the chromatogram by their color in white light.

Sensitivity of the fluorographic technique is illustrated in Figure 2B. In this chromatographic analysis of various mixtures of chlorophyll *a* and pheophytin *a*, the lower limits of detection by fluorography are indicated as 0.18 nmol (0.16 μg) pheophytin *a* and 0.65 nmol (0.58 μg) chlorophyll *a*. (Chlorophyll *a* was recorded at 0.32 nmol on the original fluorogram, but the spot was lost during photographic reproduction for publication.) By comparison, only 1.1 nmol pheophytin *a* and 1.9 nmol chlorophyll *a* could be detected by the color of the spots in white light. These results also illustrate that detection is more sensitive for some chlorophyll derivatives than for others, e.g. pheophytin *a* could be detected at levels 2- to 5-fold less than could chlorophyll *a*. As suggested by the evidence in Figure 2B, the fluorographic method can be semi-quantitative for detection of chlorophyll derivatives on chromatograms. However, self-absorption of chlorophyll *a* fluorescence probably limits not only the sensitivity of detection but also the reliability of quantitative measurement of this pigment by fluorography. Therefore, application of this technique to quantitative analysis of individual chlorophyll derivatives (and porphyrins) must be established for each compound using standardized chromatographic and fluorographic methods.

This fluorographic technique may be a useful adjunct to paper or TL chromatographic analysis of porphyrin derivatives in general. Any fluorescence-exciting light source that emits light at 380 to 450 nm, the range of Soret band light absorption of the porphyrins (Falk, 1964), can be employed. The secondary filter interposed between the chromatogram and the photographic paper must be selected for transmission characteristics to eliminate any light from the exciting source that will cause background fogging of the photographic paper. This filter should also be highly transparent to the fluorescence emitted by the spots on the chromatogram. Although only one photographic printing paper (Kodak Panalure) has been used for fluorography in this study, any photoprinting paper with a red-sensitized, panchromatic emulsion should be adaptable to the fluorography of porphyrin spots on chromatograms. Usefulness of the technique can be extended by modifications of the chromatogram before fluorography. For example, enhancement of the fluorescence by pretreatment of the chromatogram with iso-octane (Blumer, 1956) should increase the sensitivity of detection of trace components in a porphyrin mixture. Also, since some metal chelates of porphyrins do not fluoresce or fluoresce only weakly (Falk, 1964), their presence on chromatograms could be detected by their Soret band absorption. In this case the developed chromatogram should be sprayed with a solution of a fluorescent substance (Blumer, 1956), dried, then fluorographed without the secondary filter in place so that the blue-violet light absorbing spots would be recorded as white spots on a dark background.

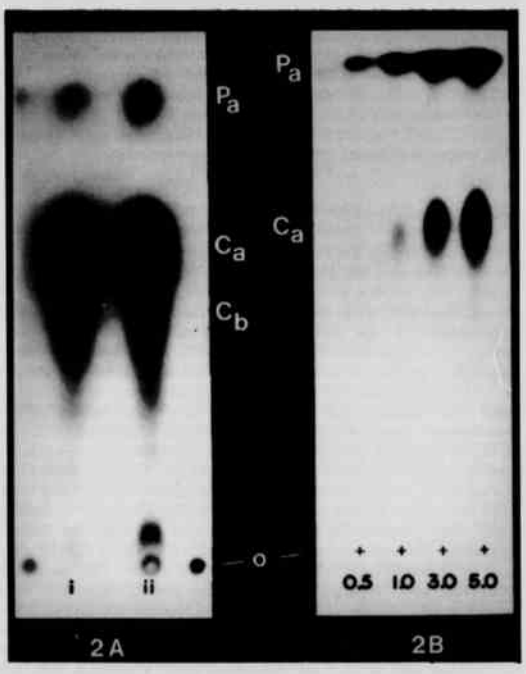

Figure 2. Fluorograms of paper chromatographic separations of chlorophyll derivatives. Ca = chlorophyll *a*, Cb = chlorophyll *b*, Pa = pheophytin *a*, o = origin.

Figure 2A: Chromatographic separation of pigments present in a fresh *Lamium* leaf extract (i) and of those present in an aged *Lamium* leaf extract (ii).

Figure 2B: Chromatographic separation of various amounts of a mixture containing chlorophyll *a* and pheophytin *a* (ratio of chlorophyll to pheophytin = 1.8:1); numbers below origin indicate the nanomoles total pigment applied at each spot.

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GENERAL NOTES

WINTER FEEDING OF FINGERLING CHANNEL CATFISH IN CAGES*

Private warmwater fish culture of channel catfish (*Ictalurus punctatus*) in the United States began in the early 1950's (Brown, E. E., World Fish Farming. Cultivation, and Economics 1977. AVI Publishing Co., Westport, Conn. 396 pp). Early culture techniques consisted of stocking, harvesting, and feeding catfish only during the warmer months. With both the refinement of culture techniques and increased marketing demands, year-round production is increasing among commercial fish farmers. However, minimal research has been conducted on winter feeds and feeding practices for catfish production. Thus, a winter feeding experiment on cage culture was conducted to determine the practicality of overwintering fingerling catfish. The objectives of the study were to determine whether or not it would be economically feasible to feed fingerling catfish in cages and to observe fingerling growth, survival, and general physical condition with and without supplemental feeding.

Fingerling catfish were stocked 1 December 1980 and harvested 13 March 1981 for a total of 103 days. Three weight-counts were taken to stock an estimated 250 fingerlings in each of six cages (2.5 kg of fingerlings). Fish were placed in 0.9 cubic meter floating cages anchored in a 1.6 ha farm pond located on the University of Arkansas at Pine Bluff Agricultural Research Station. Cage construction was identical to that of Newton and Merkowsky (1976. Using lights to attract insects for caged catfish. Ark. Farm Res. J., 25:8). Water below the cages ranged from 1.1 to 1.6 meters in depth. Three cages of fingerling catfish were fed a 36% protein ration formulated as floating pellets. Feeding rate was based upon daily water temperature (Table 1). The other three cages received no supplemental feed, thereby serving as a control. Fed caged catfish fingerlings gained an average of 411 g, an increase of 16% over initial stocking weight (Table 2). Individuals showed a significant increase from an average of 9.75 g to 12.59 g (Table 3). This gain was similar to that reported by Felts (1977. Effects of various winter feeding regimens on weight and body composition changes in channel catfish in ponds. M. S. Thesis, Auburn, University, 42 pp) for catfish reared in ponds during winter. Survival for the fed fish averaged 95%. Fed caged fish each received a total of 247 g of 36% protein ration. The catfish were fed on 43 days of the 103 day trial. Average water temperature was 10° C (50° F) and ranged from 3.3° C (38° F) to 17.2° C (63° F). Dissolved oxygen was monitored five days a week between 12:00 noon and 2:00 p.m. Dissolved oxygen averaged 11.1 ppm throughout the period.

From review of the Literature of pond studies, it was presumed that nonfed catfish would lose weight. Lovell and Sirikul (1974. Winter feeding of channel catfish. Proc. Twenty-eighth Ann. Conf. S. E. Assoc. Game and Fish Comm. 28:208-216) overwintered 0.45 kg catfish and reported that unfed fish lost 9.1% of their body weight. Felts (1977) found that unfed overwintering catfish lost 6.3% of their body weight. The nonfed fish in this study showed a slight weight gain (Table 2). Initial individual weights were 9.75 g and final weights were 10.98 g. Survival for the nonfed fish averaged 92%. The authors cannot state any definite reasons for the weight gain by nonfed catfish. Plans are to repeat this study to verify this gain. Stomach content analyses will be performed to determine if the fish are ingesting any natural organisms, such as zooplankton or small sunfishes, that may be in the cages.

Table 1. Percent of rations fed to caged fingerling catfish relative to daily water temperature from 1 December 1980 - 13 March 1981.

Percent body weight fed	Water temperature (centigrade)
No feed	=< 7
0.5	7 - 10
1.0	10 - 16
2.0	16 - 21
3.0	21 - 24
4.0	24 - 27

Table 2. Average weight gains and percent survival for fingerling catfish overwintered in cages at UA-PB.

	Cage	Total Initial weight (g)	Total Final weight (g)	Weight gain or loss (g)	Percent survival
	1	Data lost due to fish escapement			
	3	2,437	2,863	425	90
	5	2,437	2,835	397	100
	Averages	2,437	2,849	411	95
Nonfed	2	2,437	2,355	-84	87
	4	2,437	2,608	170	89
	6	2,437	2,721	284	100
	Averages	2,437	2,561	124	92

Table 3. Average individual sizes and gains for catfish overwintered in cages at UA-PB.

Cage	Individual stocking weight (g)	Individual harvest weight (g)	Individual gain (g)
3	9.75	12.76	3.01
5	9.75	12.42	2.67
Averages	9.75	12.59	2.84
2	9.75	10.78	1.03
4	9.75	11.67	1.92
6	9.75	10.50	0.75
Averages	9.75	10.98	1.23

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OCCURRENCE OF THE LAND PLANARIANS *BIPALIUM KEWENSE* AND *GEOPLANA* SP. IN ARKANSAS

Land planarians (Phylum Platyhelminthes, Order Tricladida; Suborder Terricola) are primarily long, slender flatworms found in moist, dark habitats such as under-leaf mold, boards, logs, and concrete slabs. These helminths are among the most primitive metazoans that can live successfully in a terrestrial environment. They require an atmosphere with high humidity since prolonged exposure to air presents a danger of dehydration. A protective mucous coat secreted by the planarians prevents dehydration, in part, and this material can be seen as a noticeable slime trail which marks the flatworm's migratory routes on land. The damp jungles of the tropics and subtropics are ideal for survival of Terricola, where the most abundant numbers and greatest variety of species occur (Hyman, 1951). Fewer species of land planaria are found indigenous to temperate climates, such as Europe and North America, indicating that environmental factors other than humidity may restrict the distribution of these invertebrates.

In the United States a few, relatively small (12 mm length) native land planarian species occur which include *Microplana atrocyaneus, M. rufocephalata, Rhyncodemus sylvaticus, R. americanus,* and *Diporodemus indigenous.* These helminths have been reported from various sites in

the midwest and eastern United States (Hyman, 1954; Ogren, 1955). Several exotic species of land planarians apparently have been introduced to the United States from the tropics, including *Dolichoplana striata, Geoplana vaga, G. Mexicana, Bipalium kewense,* and *B. adventitium* (Hyman, 1954). These animals are thought to have been introduced by way of imported plants, and in many cases they have been discovered in greenhouses. *B. kewense* is the most ubiquitous of these exotics and seems well established outdoors in the midsouth and southeastern United States in Florida, Georgia (Hyman, 1943), Louisiana, Alabama (Dundee and Dundee, 1963), North Carolina, South Carolina, Mississippi (Hyman, 1954), Tennessee (Chandler, 1974) and Kentucky (Cole, 1969). *B. kewense* also has been found in other areas of the U. S. such as Oklahoma (Wallen, 1954), Washington, D. C., New Jersey, Illinois, California, Hawaii and Puerto Rico (Hyman, 1943). A related species, *B. adventitium*, has been described from California and New York (Hyman, 1954; Klots, 1960; Dindal, 1970).

Two land planarians have been reported previously from Arkansas. A single specimen of *Microplana atrocyaneus* was collected at Stair Bluff, Marion County, on September 6, 1942 (Hyman, 1943). Daly et al. (1976, 1977) reported collecting *Bipalium kewense* from central Arkansas for their studies on pseudoparasitism by this worm, and further information on those collections is reported in this note.

B. kewense is a conspicuous flatworm, of 17 cm or more in length, with a pronounced lunate or spade-like head (Fig. 1A). These large land planarians are brightly marked with five dark brown stripes running the length of the body on a light brown or olivaceous background. *B. kewense* is easily seen but random searching through what appears to be typical habitat is usually unrewarding due to its relative scarcity. To increase collecting efficiency, the assistance of the *Arkansas Gazette* was requested, and the general public was asked to report the location of these animals in the Little Rock area. Field trips were made in response to these reports which provided ten sites at which successful collections of *B. kewense* were made. These sites were distributed randomly in the urban areas of Little Rock and North Little Rock (Pulaski Co.), but no sightings were made from rural or farm areas. The planarians were found under wet boards, logs, or rotting trees. Several worms were usually found at one time, and a few sites yielded more worms on repeat visits. The most productive area was a semi-natural back yard (pesticides were not used). At this site, numerous *B. kewense* were removed from under old railroad ties and concrete patio slabs. Large specimens of *B. kewense* also were reported on driveways in Little Rock after a heavy rain. Since these animals cannot survive submersion in water (Hyman, 1951), the rain must have stimulated the worms to migrate to escape flooded conditions in their usual habitat. Greenhouses were visited but, with one exception, land planarians were not found. At one nursery planaria were collected from the bottom of metal buckets used for holding saplings or bushes that were kept constantly watered. Approximately 70-80 fully differentiated and asexually produced fragments (zooids) of *B. kewense* were ultimately collected during the spring and early summer of 1971 and 1972. Also, at this time Dr. Arthur Johnson of Hendrix College reported that a student had found one specimen of *B. kewense* in Conway (Faulkner Co.) that had measured 17 cm long. In recent years the senior author has not been able to find these worms at collection sites which were previously productive. The recent lack of sightings in the central Arkansas area may be related to the relatively severe winters several years prior to 1980. Barnwell (1969) has suggested cold as a factor restricting the distribution of *B. kewense*. However, two specimens were reported to the senior author from the southern section of the state in early fall 1979, and late spring 1980, at Camden (Ouachita Co.), indicating that *B. kewense* has not disappeared from Arkansas.

In the summer of 1974 another exotic land planarian was brought to the University of Arkansas for Medical Sciences, (UAMS). This specimen was discovered under a rock by Dr. Robert Lowery in a back yard across the street from the UAMS. This planarian was flat, elongated, pointed at both ends and bluish-black (Fig. 1b). Minute eyespots were found on the peripheral edge of the worm and extended along each side to about 1/5 of its length. This planarian measured 6.5 cm in length by 1 cm in width. The initial appearance of the worm suggested that it was *Geoplana vaga*. In contrast to *B. kewense*, *G. vaga* has been found infrequently in the U.S., having been reported from California (Hyman, 1943), Georgia (Olewine, 1972), and Texas (Barnwell, 1978). However, upon microscopic examination of the genitalia (a major taxonomic feature of geoplanids), the penis did not match the original description for *G. vaga* by Hyman (1943). Sections of this specimen have been sent outside the country to an authority on *Geoplana* taxonomy for further study. The organism is apparently either a new species of *Geoplana* or a species of *Geoplana* newly described in the United States, or both.

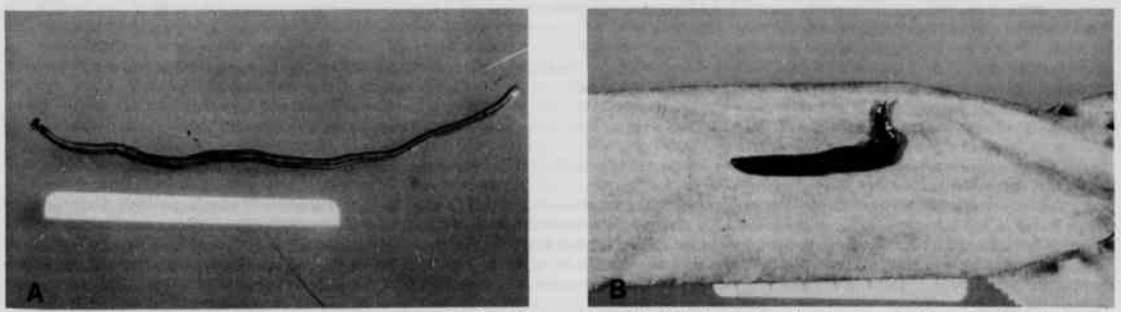

Figure 1. (a) A fully differentiated *Bipalium kewense* showing the spade-like head and the longitudinal, dark linear stripes. (B) *Geoplana* sp. found in the central Arkansas (Little Rock) area. The anterior end of this land planarian is more slender and pointed than the posterior end. Both figures are approximately life-size.

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ADDITIONAL RECORDS AND UPDATES ON THE ARKANSAS FLORA

During 1979 and 1980 the Arkansas Natural Heritage Inventory Program conducted field surveys to assess vascular plant rarity in the state. Five taxa were discovered new to the flora of Arkansas:

Psoralea digitata T. & G. var. *digitata*. MILLER COUNTY; scattered in a sandy churchyard northwest of Doddridge about 4.0 Km north of Hwy. 160 and Hwy. 237 junction. Davis and Kral 2689, 25 June 1980. Shinners (Field and Laboratory 19:14-25, 1951) cites a Nuttall voucher of this taxon from "sandhills of the Red River, Arkansas Territory." Since it is impossible that this voucher was collected in either Oklahoma or Arkansas, it should be treated as a new record in Arkansas.

Tradescantia reverchonii Bush. MILLER COUNTY; sparse on very sandy soils northwest of Doddridge about 1.1 Km south of the junction of Hwy. 237 and Hwy. 134, T18S R28W, Sec. 17, E ½ NW ¼. Davis and Tucker 2580, 17 June 1980.

Aletris aurea Walt. MILLER COUNTY; local in a moist, mowed pine-barren about 2.4 Km north of Fouke on west side of Hwy. 71, T17S R27W, Sec. 9, SW ¼ NW ¼. Davis and Tucker 2547.

Xyris baldwiniana R. & S. CALHOUN COUNTY; small remnant of savannah in railroad and gravel road rights-of-way, 2.1 Km north of Hwy. 172 along road paralleling railroad east of Hwy. 67. Davis and Roberts 2606.

Rhynchospora rariflora (Michx.) Ell. CALHOUN COUNTY; same location as above cited *Xyris*. Roberts and Davis 1500.

The *Rhynchospora rariflora* voucher is deposited in Vanderbilt University and the remaining vouchers are filed in Arkansas Tech University.

Four species which had previously been reported to Arkansas were confirmed with vouchers. Demaree (Taxodium 1:1-88, 1943) reported *Rhynchospora cephalantha* Gray, but the location of the voucher was unkknown until located in February, 1980 at Vanderbilt University. This voucher is annotated by Robert Kral. *Carex latebracteata* Waterfall has been vouched from Polk, Garland and Howard counties, and specimens are deposited in Vanderbilt University Herbarium (Davis and Tucker 2124; Davis, Pell and Smith 2146; Davis and Shepherd 2159). *Anthaenantia rufa* (Ell.) Schult. was confirmed from both Bradley and Drew counties (Davis and Pell 1896; Davis and Shepherd 2820b). This species was reported without voucher by Moore (Proc. Ark. Acad. Sci. 15:9-25, 1961). After having been considered extirpated, five stems of *Cypripedium reginae* Walter were discovered in Stone County (Davis and Foster 2414). The previous two species are deposited in Arkansas Tech University Herbarium.

The author is grateful to Dr. Robert Kral and Jerry Roberts, who deferred reporting two of these state records. Thanks are due to The Nature Conservancy under whose funding this research was conducted.

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OBSERVATIONS ON THE OCCURRENCE OF CHALKY DEPOSITS ON FOREWINGS OF *ONCOMETOPIA ORBONA* (F.) (HOMOPTERA: CICADELLIDAE)

Many homopterans produce a chalky or waxy, white material. Metcalfe (1969) mentioned that the most distinctive feature of the nymphs of the delphacid *Saccharosydne saccharivora* (Westw.) was the white wax rods formed on the head, tail, and lateral abdomen. He added that among adults the white wax was present only on females.

General Notes

Oncometopia orbona (F.) is a large cicadellid in the tribe Proconiini, a group commonly called sharpshooters. This species is a vector of phony peach disease virus and Pierce's disease virus of grape (Nielson 1968). Individuals of *O. orbona* frequently possess conspicuous white deposits as a globular lump on each forewing (Fig. 1: see also Borror and White 1970, p. 131, and Fenton 1952, p. 242). Riley and Howard (1893) described similar deposits on the wings of female *Homalodisca coagulata* (Say), another proconiine leafhopper.

Swain (1936) described oviposition into plant tissue by *O. undata* Fabr. (=*orbona*), which is followed by scraping the hindlegs over the chalky deposits and coating the egg scar with the white powder. He suggested the powder was camouflage for hiding the eggs from parasites or predators.

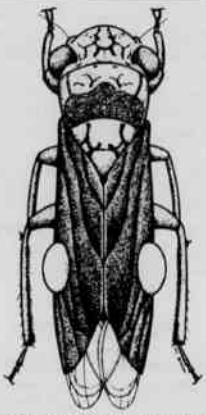

Figure 1. Drawing of *Oncometopia orbona* (F.) female with chalky deposits on forewings (dorsal view).

Turner and Pollard (1959) mentioned that females of *H. coagulata* and *H. insolita* (Walker), as well as *O. undata*, coat their egg batches. They said that "... gravid females transfer some of the chalk from the tips of their bodies to their elytra by means of their hind tibiae." Pollard and Yonce (1965) described the presence of long tibial spines on the hindlegs of those female proconiines which produce chalky spots on their forewings and coat their oviposition sites with white powder. Males of all species and females of species lacking the deposits have shorter tibial spines.

Severin (1950) mentioned a peculiarity in oviposition by the nonproconiine cicadellid *Texananus incurvatus* (Osborn and Lathrop): "After inserting the egg in the [celery] petiole, the female secretes a liquid (which becomes white when dry) in the form of threadlike papillae over each egg puncture." Metcalfe (1969, Plate XVII, Fig. 4) recorded that females of *Saccharosydne saccharivora* deposit wax threads at the oviposition site.

Storey and Nichols (1937) made no mention of oviposition in describing a special method of defecation by both nymphs and adults of a small nonproconiine leafhopper, *Cicadulina mbila* Naude. Adults transfer drops of a "viscid opaque yellowish fluid" from the anus onto tibiae of hindlegs, spread the drops on upper surfaces of wings, and then scrape the dried material off the wings with violent cleaning movements of the legs. Although the authors were not explicit, it is assumed that both sexes exhibit this behavior. Nymphs transfer the drops from the anus onto tarsi of hindlegs, and by slow kneading movements of all legs, distribute the material onto the legs where it dries. Cleaning movements by nymphs continue until the material falls as a powder. The authors hypothesized that the cloudy feces enable elimination of products excreted through the Malpighian tubules.

Specimens of *O. orbona* (both sexes) were collected from various localities in Illinois during the summers of 1974-76 in order to observe them in the laboratory and to determine the significance of the white chalky material regarding oviposition and/or excretion.

Adults of *O. orbona* taken in the field from milkweed plants (*Asclepias incarnata* L. and *A. syriaca* L.) and sunflower (*Helianthus* spp.) were brought into the laboratory and placed in acetate cylinder chimney cages over potted milkweed and sunflower plants for observation. Record was made of any behavior associated with the chalky deposits, oviposition, or excretion.

Thin-layer chromatography was used to qualitatively determine which arthropod excretory products were present in the chalky material. Lithium carbonate was used as a solvent. Spots of the chalky material along with known spots of urea, allantoin, uric acid, adenine, quanine, cytosine, thymine, and uracil were placed on silica gel plates which were developed two-dimensionally in methanolconc. HCl-H_2O and butanol-methanol-H_2O-NH_4OH tanks.

Of the 14 *O. orbona* adults (8 ♀♀, 6 ♂♂) observed in the laboratory, six (all ♀♀) had chalky deposits on their forewings at some time. Only one female was observed ovipositing and then scraping the chalky deposits onto the egg site. Three different females were observed scraping off their chalky deposits, although exhibiting no oviposition behavior. Four females, with deposits one day, had scraped the material off their wings by the next day without making any signs of oviposition sites on the plants in the cages. Thus, only one of the eight recorded instances of removal included actual oviposition.

Examination of 60 *O. orbona* adults in the insect collection of the Field Museum of Natural History in Chicago revealed that only four (all ♀♀) had chalky deposits, while the Illinois Natural History Survey collection revealed that of 110 individuals, seven (all ♀♀) had deposits.

Thin-layer chromatography analysis of the chalky material indicated that urea was present. Both Rf values and ninhydrin color reaction also showed that allantoin was present in the chalky material.

Observations of *O. orbona* in laboratory cages indicated two methods of apparent defecation. In one, tiny clear liquid droplets (ca. 1 mm diam.) were flung from the anus, often in rapid succession, for several minutes. These droplets dried, leaving only a slight film on the cage walls. The other method involved large drops (up to 6 mm diam.) of clear liquid issuing from the anus and collecting under the posterior edges of the folded wings. When a drop touched the host plant, surface tension was broken and liquid flowed down the plant. On one occasion a large drop was flung vigorously against the cage wall by the leafhopper, and the insect then expelled small droplets as described above. Another large drop

formed and the leafhopper used its hindlegs to touch the drop; this was followed by intensive "kneading" movements of the legs. Again this behavior was followed by normal small-droplet defecation. The liquid material from the large drops consistently dried as a two-dimensional, translucent film.

Chalky deposits on the forewings of *O. orbona* appear to be restricted to females, and an ovipositing female can certainly scrape the chalky material onto an egg site. But non-ovipositing females with chalky deposits will also scrape the material off their wings.

Powdery white material on an otherwise green oviposition site seems an unlikely visual camouflage against predators and parasites, but it may be a chemical protection for the site. A white fungus began growing on a sunflower plant stem where oviposition and scraping behaviors were observed in the laboratory. The growth was much less extensive several days later in the deposit area than it was on the uncovered parts of the stem.

The antibiotic properties of allantoin became apparent earlier this century in connection with the "maggot therapy" of treating certain types of human wounds (Robinson 1935). The presence of allantoin in the chalky material from *O. orbona* could protect the oviposition site from microbial attack.

None of the literature describes the appearance of the chalky material on *O. orbona* before it is placed on the wings and dries. Turner and Pollard (1959) were vague about the physical form of the substance, saying only that "... gravid females stroke the tips of their bodies with their hind tibiae, transferring some of the chalk to their legs." I have never seen in *O. orbona* the opaque yellowish drops described by Storey and Nichols (1937) for *Cicadulina mbila*.

DeLong (1971) described the proconiine leafhoppers as xylem-feeders. In the meadow spittlebug *Philaenus spumarius* (L.), this method of feeding results in copious excretion of water (Wiegert 1964) without the familiar honeydew excreted by phloem-feeding homopterans. Observations of the excretion of copious amounts of clear liquid by *O. orbona* exemplify this situation.

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OBSERVATIONS ON SIZE AND FECUNDITY OF THE LEAST BROOK LAMPREY, *LAMPETRA AEPYPTERA* (ABBOTT), FROM NORTHCENTRAL ARKANSAS

Information on the least brook lamprey *(Lampetra aepyptera)* in Arkansas is limited to reports of distributional data (Robison, 1974; Harp and Matthews, 1975; Sewell et al. 1980). This is based on the fact that only 32 *L. aepyptera* are known from Arkansas (Sewell et al. 1980). However, in other parts of its range, *L. aepyptera* has been extensively studied (Schwartz, 1959; Brigham, 1973; Pflieger, 1975; Rohde et al. 1976; Rohde, 1977; Rohde and Jenkins, 1980).

The purpose of this investigation was twofold: first, to provide quantitative data for Arkansas *L. aepyptera* to compare with data reported from other portions of its range, and second, to provide foundation for future studies of the biology of the least brook lamprey in Arkansas.

Thirteen mature *L. aepyptera* were collected on 30 March 1980 with a 1.8 × 0.9 m straight nylon seine (3.2 mm mesh) from North and South Sylamore Creeks, Stone County, Arkansas (T.16N, R.12W, Sec.16; T.15N, R.11W, Sec.21). Of these, seven were males, and six were females. Total length to the nearest mm and weight to the nearest 0.01 g were obtained from all formalin-preserved fish. Mid-ventral incisions were made in females and ovarian compliments removed, weighed and preserved separately. Eggs were not free in the coelomic cavity, suggesting that spawning had not begun. Actual counts of ova were made utilizing a binocular microscope. Diameters of 20 ova were measured in each of six females to the nearest 0.01 mm with an ocular micrometer.

Mean and standard deviation ($\bar{X} \pm$ s.d.) were calculated for each character examined. Sexes were compared with a one way analysis of variance (ANOVA) test. The relationship in females between characters was examined by correlation analyses. The Statistical Package for the

Social Sciences (SPSS) were performed in all statistical procedures. Lamprey voucher specimens are deposited in the Arkansas State University Fish Museum (ASUM #9326-9339).

The mean total length was 119.2 ± 6.26 mm (range 108-125), while mean weight was 2.59 ± 0.53 g (range 2.01-3.24) in males. The total lengths were slightly higher than those reported by Seversmith (1953). The mean total length was 125.6 ± 5.24 mm (range 116-132), while weight ranged from 2.15 to 3.36 g ($\bar{X}$ = 2.97 ± 0.42) in females. Seversmith (1953) and Rohde et al. (1976) reported mean total lengths of 103.6 mm and 98.5 mm for Maryland and Delaware *L. aepyptera*, respectively. Rohde et al. (1976) reported weight ranges of 0.9 to 3.0 g ($\bar{X}$ = 1.8). Mean weight is substantially higher than that reported by Rohde et al. (1976); however, his sample included three transforming *L. aepyptera*. Ova counts per individual ranged from 824 to 1,624 ($\bar{X}$ = 1306 ± 302) and are similar to the 1,164 eggs reported from one specimen by Seversmith (1953) for Maryland *L. aepyptera*, but substantially higher than the mean of 874 eggs reported for Delaware *L. aepyptera (Rohde et al. 1976)*.

Mean egg mass was 0.76 ± 0.21 g (range 0.43-1.00). Egg diameter ranged from 0.84 to 1.24 mm ($\bar{X}$ = 1.02 ± 0.08). These data are consistent with that reported by Rohde et al. (1976) and suggest an extreme uniformity between individual egg diameter. The relative fecundity index (no. eggs/ g body weight) for the six female adults ranged from 383.2 to 534.8 ($\bar{X}$ = 436.5 ± 56.4). Although slightly lower, these values accord well with those reported by Rohde et al. (1976) for *L. aepyptera* and Hardisty (1971) for other non-parasitic lampreys.

Neither total weight nor length was significantly different between males and females in this study (ANOVA, F=1.92, p=0.19; F=3.88, p=0.07, respectively). All correlations (Table 1) except egg count-total length and egg weight-total length were significant (ANOVA, p<.05).

Table 1. Correlation matrix for comparison among characters of six female *Lampetra aepyptera* from northcentral Arkansas.

	TOTAL LENGTH	TOTAL WEIGHT	EGG COUNT	EGG MASS WEIGHT
TOTAL LENGTH	1.000			
TOTAL WEIGHT	0.821	1.000		
EGG COUNT	0.615	0.877	1.000	
EGG WEIGHT	0.571	0.862	0.977	1.000

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LICHENS OF ARKANSAS II. ADDITIONAL STATE RECORDS THROUGH COMPUTER SEARCH

The lichen herbarium of the American Bryological and Lichenological Society (ABLS) is housed along with the University of Minnesota herbarium (MIN), at the University of Minnesota. Both collections have been computerized (Wetmore, C.M. 1979. Herbarium computerization at the University of Minnesota. Systematic Botany 4(4):339-350.) and are separated from each other by different data bases. Printouts of the Arkansas lichens contained in these herbaria revealed additional records for Arkansas lichens not previously reported (Moore, Jewel E. 1979. Lichens of Arkansas I. A summary of current information. Proc. Ark. Acad. Sci. 33:85-87.): *Leptogium sinuatum* (Huds.) Mass., *Physcia constigata* (Nyl.) Norrl. and Nyl., and *Caloplaca flavovirescens* (Wulf.) Dalla Torre and Sarnth collected by C. Wetmore in Franklin County, Ozark National Forest, Cherry Bend Campground, 1 June 1966; *Peltigera malacea* (Ach.) Funck collected by Delzie Demaree on West Mountain, Hot Springs National Park, 9 March 1954; *Cladonia cariosa* (Ach,) Spreng. collected by Delzie Demaree at Optimus, Stone County, 20 May 1960; and *Cladonia pyxidata* (L.) Hoffm. collected by Delzie Demaree at Daisy, Ouachita National Forest, in Pike County, 6 January 1963.

These six additions to the lichens of Arkansas bring the state list to 241 species. The systematic synopsis of the lichens of Arkansas, with common names (from Nearing, G. G. The Lichen Book. Publ. by the author. Ridgewood, New Jersey) is available from Arkansas Biota (Moore, Jewel E. 1981. Systematic synopsis of the Lichens of Arkansas. Arkansas Biota, publ. by Ark. Acad. Sci.).

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CROWLEY'S RIDGE BIOLOGICAL STATION—AN EDUCATIONAL CENTER

Arkansas may be divided into two principal regions based upon topography, geological substrate, and dominant vegetation—the Interior Highlands of the northwestern part of the state and the Gulf Coastal Plain of the southeastern part. Within the Gulf Coastal Plain is the unique geological feature known as Crowley's Ridge (Call, 1891; Foti, 1974). The ridge rises about 250 feet above the flat Mississippi Alluvial Plain and extends about 150 miles in length from Helena northward into Missouri. Crowley's Ridge Biological Station is located on two acres on Titanic Road, about two miles south of Pollard, in Clay County. There are two buildings which can be used for pioneer-type living and for laboratory work. The site is near some of the gravel pits so characteristic of the upper part of the ridge where gravel and sand are obtained for commercial uses. Surrounding the station are forest stands of oak-hickory-tulip poplar and fields for pasture and wheat production. Deep gullies, frequently encountered on the ridge, and petrified wood of trees from the Eocene Tertiary gravels are found in some of these fields.

While the station itself is small, there are ample opportunities for field studies associated with Crowley's Ridge. Big Lake National Wildlife Refuge in Mississippi County, and the adjacent Arkansas Game and Fish Commission lake yield good habitats for studying game and waterfowl associated with such cypress lakes. This area is part of the Sunken Lands which resulted from the New Madrid Earthquake of 1811-13. Also in Mississippi County are the heronries near Luxora and Burdette from which the state record for nesting glossy ibis was first reported (Hanebrink and Cochran, 1966). Other nesting species at these heronries include little blue heron, great egret, cattle egret, snowy egret, Louisiana heron, and black-crowned night heron. Other records for nesting birds and bird migrations are needed to complete the work already begun on these ridge inhabitants (Hanebrink, 1980). Research on the fishes of Crowley's Ridge has been published (Fulmer and Harp, 1977), but field studies on other animals of the ridge are needed.

Research on the forest stands of Crowley's Ridge (Clark et al., 1974; Clark, 1977) indicates that the oak-hickory-pine edaphic climax forest and the white oak-beech stands (present status of the beech-maple climax forest) establish baselines allowing comparison of the extant and extinct forest stands of the ridge. As a rule, the oak-hickory-pine forest follows the irregular outcroppings of the droughty soils in the northern part of the ridge; the white oak-beech stands coincide with the Pleistocene loess which covers the southern portion of the ridge and disappears on the ridge summits where the Tertiary sands and gravels produce the soils of the Brandon-Lexington association. The tulip poplar, unique to the Crowley's Ridge area of Arkansas, reproduces in the cut-over white oak-beech forests. Mud slides also are conducive to this invasion, as well as to invasion by the cucumber magnolia. The relict stand of two trees of bigleaf magnolia (Moore, 1953; Figler, 1981) is in Clay County; as is Chalk Bluff Natural Area (Marsh, 1977), which can be used for sampling and describing the forest types of the ridge. The distribution of Arkansas vascular plants (Smith, 1978) indicates a need for basic inventory-type field work on the ridge and throughout the state.

A field studies class from the University of Central Arkansas used Crowley's Ridge Biological Station to make excursions to some of these habitats on the ridge. The station is not so large, nor as developed, as the Ouachita Biological Station (Spears, 1976), but it can be used as a research center for individuals or college classes to study Crowley's Ridge.

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RATION/DENSITY COMPARISONS WITH CAGED CHANNEL CATFISH*

Caged fish culture as a production method for rearing catfish and trout was first started in the United States in the late 1960's and has now become more practical than ever for certain situations (Newton, 1980). This is especially true for the utilization of farm ponds which are suitable for cages because the fish cannot be easily harvested otherwise. Since 1967, university and governmental researchers have studied and developed caged catfish culture for the fish farming industry (Lewis, 1969; Schmittou, 1969; Collins, 1971). They first dealt with culture techniques involving potentials and adaptations of the method. They used numerous types of cages and gradually refined studies to include nutritional trials, stocking sizes and rates, genetics, and fish health (Collins, 1978).

Research conducted during the 1970's, primarily in Arkansas and Oklahoma, has further refined cage culture methodology and application potentials (Collins, 1971; Collins, 1978; Newton, 1980; Kilambi et al., 1977). These studies are valuable because they demonstrate the variety of situations for using cage culture, the improved feed quality for confined fish culture, and the resource potential for both home and commercial ventures.

Cages are ideal for evaluating rations for fish diets (Newton and Dean, 1978; Newton et al., 1980). The need continues for testing available rations for efficient and economical fish production. This study compares two rations of similar protein levels, 33% and 36%, but quite different in cost with three stocking densities of channel catfish.

A total of 18 cages were stocked with catfish fingerlings during May 1980. The cages (0.9 m^3) were arranged in units of three across the south end of a 1.6 ha farm pond on the University of Arkansas at Pine Bluff Agricultural Research Station as described previously by Newton and Merkowsky (1976). Six cages were each stocked with 200, 350, and 500 fingerlings (average wt. 28 g), respectively, in a randomized pattern. Experimental conditions were triplicated simultaneously for ration and density evaluations. Three cages of each fish density were fed either a 36% protein trout ration or a 33% protein catfish ration formulated as floating pellets. All fish were fed five days per week at the rate of 4% of their estimated body weight, regardless of density or ration combinations.

The study period began 14 May and ended on 30 August due to an oxygen depletion which killed fish in approximately two-thirds of the cages. Nevertheless, all data were collected from each cage similar to usual harvest operations in previous studies (Newton et al., 1980). Statistical comparisons revealed no significant differences between data collected from dead or live fish. Therefore, the relative validity of the assumptions and determinations reported herein are believed to be accurate for practical comparisons among density and ration combinations.

Evaluations of the rations and stocking densities were based upon weight gain, food conversion efficiency (FCE), survival, and production costs per kilogram of catfish produced. Comparisons between rations revealed no significant differences among net production, FCE, and survival. Due to the difference in feed costs (the 33% protein ration was $16/45.5 kg, while the 36% protein ration was $25/45.5 kg) the 33% protein ration was the most cost efficient at all stocking densities (Table 1). With either ration, the cost per kilogram of fish produced was less at the higher stocking densities (350 and 500 fish); however, production costs were still lower for all densities with the 33% protein catfish ration. The greatest net profit per cage was obtained with the highest fish density for both rations.

There were significant differences in net production among each stocking density, although survival and FCE were similar (Table 2). Fish stocked at 350 per cage had higher average individual gains than fish stocked at 200 or 500 per cage, which had similar average gains. Both FCE and survival were consistently within normal ranges necessary for successful caged catfish production. Survival was unusually high, until the occurrence of the oxygen depletion. One of the disadvantages of cage culture is that caged fish are more susceptible to oxygen problems than fish in an open pond.

Since the fish stocked at 350 per cage had higher individual gains with both rations, it appears that this stocking density was optimum for producing larger size fish. Fish density considerations have been studied for some time (Schmittou, 1969; Konikoff and Lewis, 1974), and it has been determined that generally a minimum number of 5-6 fish per 30 cm^3 is required to avoid behavioral problems. We have used 7-8 fish in most of our studies; however, the maximum or optimum number to stock deserves further attention. A high quality, less expensive catfish ration outperformed a more expensive trout ration on the basis of fish production, economy, and availability.

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Table 1. Economics of raising channel catfish in cages with either a 33% ration or a 36% ration.

Ration	Stocking density	Gross sales	Total expenses	Net profit per cage	Production cost/kg of fish
33% protein catfish ration	200	$ 69.98	$ 49.08	$ 20.90	53c
	350	$142.00	$ 78.16	$ 63.84	41c
	500	$162.43	$ 90.52	$ 71.94	42c
36% protein trout ration	200	$ 65.90	$ 57.44	$ 8.43	65c
	350	$140.03	$ 98.02	$ 42.01	52c
	500	$166.24	$112.37	$ 53.87	51c

33% protein ration 35¢/kg
36% protein ration 55¢/kg

Channel catfish live weight selling price $1.65/kg

Fixed expenses:
Cage cost and depreciation (5 yrs)

Variable expenses:
Fingerlings, feed, and labor

Table 2. Production of channel catfish reared in cages at three stocking densities and fed 33% and 36% protein rations.

33% protein ration				
Stocking density	Percent survival	Net production (kilograms)	Food conversion efficiency	Average fish gain (grams)
200	94	37	1.14	196
350	99	77	1.29	221
500	95	85	1.27	181
36% protein ration				
Stocking density	Percent survival	Net production (kilograms)	Food conversion efficiency	Average fish gain (grams)
200	90	34	1.22	193
350	97	75	1.33	235
500	99	87	1.25	176

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ECONOMICS OF RAINBOW TROUT PRODUCTION IN ARKANSAS*

The major area of rainbow trout *(Salmo gairdneri)* production in Arkansas is the northwest section of the state. This region is noted for its karst topography with associated underground rivers and springs having ideal water supplies and temperatures for trout production. With increased trout usage for both recreational purposes and personal consumption, northwest Arkansas trout producers presently cannot meet demands. By contrast, the delta areas of Arkansas have copious amounts of shallow, easily obtainable water and readily available production sites that are being used seasonally for producing farm raised channel catfish *(Ictalurus punctatus)*. Collins (1972) and Newton et al. (1977) reported that trout may be reared in cages and ponds in southern Arkansas when water temperatures remain below 21° C. This condition occurs seasonally, usually November through April.

The objectives of this study were to further refine pond production methods and to consider the economic potentials of winter trout rearing in the southern portion of the state.

Fish averaging 119 g each were obtained from a northwest Arkansas commercial producer in November, 1979. Fish were conditioned from raceways to ponds and cages for three weeks before commencing the study. One portion of the experiment consisted of stocking 150 trout in each of three 0.9 cubic meter cages anchored in a 1.6 ha stock pond. The second part consisted of stocking two 0.1 ha ponds each with 500 fish. Both trials were conducted simultaneously at the University of Arkansas at Pine Bluff Research Station from 18 November 1979 through 1 April 1980.

All fish were fed a 36% protein commercial floating trout ration. Caged fish were fed five days a week, while pond fish were fed every day. The caged fish were fed on fewer days than the pond fish because they were set up on a different feeding schedule from the pond fish. Feeding rates were adjusted according to water temperature (Klontz, 1978) and were calculated as a percentage of body weight which was estimated bimonthly (based on an assumed growth rate of 1.7:1 feed conversion efficiency (FCE) or 3.74 kg of food fed for 1 kg of fish produced).

The average total weight harvested per cage was 29.05 kg, a total net gain of 10.64 kg over average initial stocking weight (Table 1). Survival averaged 89% for the caged trout. Fish increased from an average individual size of 122 g to 216 g each during the period, for a 79% average gain. This was similar to growth rates obtained in previous studies in Arkansas (Collins, 1972; Newton et al., 1977). Food conversion efficiency was 1.75:1, higher than that of the previous studies.

The harvest weight of pond-reared trout was 121.36 kg (1213.6 kg/ha), a net gain of 53.8 kg over initial stocking weight (Table 2). Trout survival in ponds averaged 99.5%, which was also similar to that reported earlier by Newton et al. (1977) but higher than survival reported by Kilambi et al. (1977) and Collins (1972). Individual trout increased from 136 g to an average of 245 g in the ponds. The FCE of trout produced in ponds was 1.65:1. There was a noted difference among fish from the two ponds in both total net production and FCE. These differences may be partially explained by variation in water quality between ponds. During the entire period, fish were observed actively feeding in one pond, while only sporadically in the other pond.

Water temperature during the study period averaged 10° C and ranged from 3.8 C - 15.4 C (Fig. 1). Klontz (1978) noted that food conversion efficiency and activity of trout were favorable until water temperature dropped below 10° C. He reported an optimum temperature level of 14.4° C for trout feed consumption. Growth of trout slowed below 8° C and ceased below 5.6° C. During our study, conditions for growth were favorable 75% of the study period and were best for trout production 40% of the time. November, December, March, and April were the best months for trout production.

Winter culture of trout appears quite economically promising. Cages stocked with 150 fish yielded a net profit of $17.10 per cage. Profit would be slightly lower if labor costs were subtracted. Expenses per cage for the growing season were: feed $10.20 ($0.55/kg) and $49.50 for fingerlings ($0.33 ea). Live weight wholesale price was $2.64 per kg. If trout were marketed on a retail market as opposed to wholesale ($4.07/kg), a net profit of $56.70 per cage would be reasonable. Kilambi et al. (1977) found that a stocking rate of 300 fish per cubic meter did not significantly limit growth of caged trout.

Pond-reared trout, at a stocking rate of 5000 per hectare and a harvest weight of 1169 kg, would net $433.96 per hectare based upon a live-weight selling price of $2.64 a kilogram. Expenses (per hectare) were: feed cost $1061.61 ($0.55/kg), and fingerling cost of $1590.60 ($0.33 ea). Profit margins may be increased by higher stocking rates. Jenson (1979) found that a stocking density of 8650 fish per hectare was not limiting to growth of trout in Alabama ponds.

Trout reared along with catfish in ponds during winter, as reported by Reagan and Robinette (1975) and Newton et al. (1977), had a net return on a per hectare per year basis which was higher because the two fish crops could be harvested yearly. Polyculture of trout and catfish also is feasible because nearly 90% of the trout can be captured with only one seine haul without harvesting the catfish. This combination reduces the

extra expenses of multiple seinings and sorting common to most polyculture situations. Any remaining trout not captured during the spring harvest would not be totally wasted in catfish production ponds.

Rainbow trout can be successfully and economically reared during the winter season in southern Arkansas. Profits of $44.00 per 0.9 m^3 cage and $780.00 per hectare are obtainable. Producers should stock trout weighing at least 113 g to obtain marketable size fish in one growing season. Smaller operations should sell their fish on local markets to both obtain higher prices and take advantage of the maximum length of the growing season. Most trout growth is obtained during November and December and again near the latter part of the season during March and April when water temperatures range between 10-16° C.

Table 1. Net production, food conversion efficiency, percent survival, and average weight gained for rainbow trout reared in cages.

Cage	Stocked weight (kg)	Harvested weight (kg)	Weight gain (kg)	FCR	Percent survival	Individual Averages Stocked (g)	Harvested (g)	Gain (g)
1	18.18	29.45	11.27	1.61	89	122	318	96
2	18.64	29.50	10.86	1.70	87	122	224	102
3	18.45	28.27	9.87	1.89	91	122	207	85
Averages	18.41	29.05	10.64	1.75	89	122	216	95

Table 2. Net production, food conversion efficiency, percent survival, and average weight gain for rainbow trout production in Arkansas ponds.

Pond	Stocked weight (kg)	Harvested weight (kg)	Weight gain (kg)	FCR	Percent survival	Individual Averages Stocked (g)	Harvested (g)	Gain (g)
1	69	113	44	1.93	100	136	227	91
2	68	130	62	1.37	99	136	264	128
Averages	68.5	122	53	1.65	99.5	136	245	109

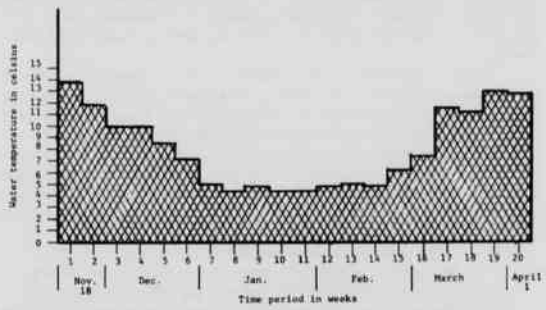

Figure 1. Average weekly water temperature of a 1.6 ha pond at 0.5 meter depth in southeast Arkansas during the winter of 1979-80.

Sincere appreciation is extended to Calvin J. Haskins for supervising the care and feeding of the trout reared in ponds. We would also like to thank Dr. Gaynor Burleigh and Dr. E. L. Torrans who provided critical review of the manuscript. Special thanks go to the Arkansas Game and Fish Commission Joe Hogan State Hatchery biologists for fish transportation. This study was supported by funds provided by USDA, SEA/CR PL 95-113.

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THE STATE OF CYTIDINE 3', 5' CYCLIC MONOPHOSPHATE (CYCLIC CMP) RESEARCH

The status of cyclic CMP is unclear although the presence of cyclic CMP radioimmunoreactive material (CRIRM) has been demonstrated in a variety of biological tissues and fluids. Furthermore, marked changes in cyclic CMP and CRIRM have occurred at certain times after partial hepatectomy during liver regeneration. In addition, CRIRM is known to increase in cell free systems thought to synthesize the nucleotide from cytidine triphosphate. Several cyclic CMP phosphodiesterases have been demonstrated. Argument about the occurrence of cyclic CMP has arisen because although CRIRM co-chromatographs with both unlabeled authentic cyclic CMP and ^{3}H-cyclic CMP on a number of TLC systems, CRIRM has a different Rf from that of ^{3}H-cyclic CMP or unlabeled cyclic CMP on Dowex-1-formate anion exchange chromatography of acid soluble extracts of biological tissue.

The discovery of cyclic AMP and the development of the second messenger concept constituted a revolution in biological thinking (Sutherland, 1972). In contrast, after almost ten years of research in cyclic CMP, it remains uncertain that this nucleotide is a naturally occurring compound or that it has any biological function at all. For example, in 1980 the only publications in this area were two abstracts on cyclic CM phospodiesterases (PDE) (Conrad and Bloch, 1980; Helfman et al., 1980), and another communication (Murphy and Stone, 1980) on apparent changes in cyclic CMP concentration during liver regeneration. In 1981, only two communications have appeared so far; (Wikberg and Wingren, 1981) one on non-identity of CRIRM with authentic cyclic CMP and (Scavennec et al., 1981) the other on the occurrence of cyclic CMP in the urine of

normal and leukemic patients. Thus, it is possible to review the salient points of the literature in this area in a very short paper and, in so doing, explain the reasons for the difficulties.

Cyclic CMP was synthesized in 1961 by Smith et al., along with the cyclic analogs of the monophosphates of adenosine, guanosine and uridine. When Steiner and his group (1972) developed radioimmunoassays for most of the cyclic nucleotides, cyclic CMP was omitted. The reason was that cyclic CMP is insoluble in pyridine, the solvent used in the succinylation reaction which attaches a succinyl moiety at the 2' position of the ribose while succinic anhydride serves as the reagent. The succinyl moiety at position 2 serves several very important functions in the development and function of a radioimmunoassay: 1) It serves as a point of attachment for a large protein molecule which makes the compound antigenic when injected, along with Fruend's reagent, into the toe pads of rabbits; 2) It serves as a point of attachment for a methyl tyrosine moiety, which, in turn, is iodinated with ^{125}I. The succinylation with succinic anhydride, surprisingly, could have been carried out in water. The reactions are shown in Figure 1. The highly radioactive ^{125}I methyl tyrosine ester of 2' succinyl cyclic CMP binds to the antibody in the assay and can be displaced by cyclic CMP either as known standards or cyclic CMP present in unknown samples. Figure 2 demonstrates a radioimmunoassay control curve.

Figure 3 shows the cross reactivity of the antibody with other cyclic nucleotides, most of which, with the exception of cyclic AMP, present no problems. Radioimmunoassays of this type were developed almost simultaneously during 1978-79 (Cailla et al., 1978; Murphy and Stone, 1979) and again recently (Wikberg and Wingren, 1981). A commercial assay from Collaborative Research, Walthan, Massachusetts, is also available.

However, it should be emphasized that the founder of this area of research is actually Alexander Bloch of the Roswell Park Memorial Institute, who, from 1970 to the present, has accomplished the following basic research:

1) He has demonstrated that cyclic CMP is present in relatively large amounts (nMoles) in mammalian liver, L 1210 cells and that it increases in regenerating liver. Bloch characterized cyclic CMP in a number of ways: Rf values in eight different thin layer chromatographic (TLC) solvent systems, electrophoretic mobility in three different buffers, UV spectra, and mass spectral analysis (Bloch, 1974a).

2) He has demonstrated that the addition of cyclic CMP to L 1210 cells, which had previously been synchronized by cooling to 4° C, produced a burst of mitotic activity. He concluded that the cultures had been synchronized at the G_2 phase since the cells could not likely traverse the cell cycle in 15-30 min. Thus, Bloch was the first to associate cyclic CMP with the mitotic phase. He also showed that the addition of cyclic CMP reversed the inhibition of growth produced by cyclic AMP in the L 1210 cultures (Bloch et al., 1974).

Bloch considered that, despite all these data, definitive proof of cyclic CMP as a normal physiological cellular component had to await the demonstration of its enzymatic synthesis in the cell from which it had been isolated. Bloch did not have a radioimmunoassay available but was forced to rely on TLC which is less accurate quantitatively and much more time consuming. Cyclic CMP has also been found in surprisingly high concentrations (0.05-2.0 nM) in bacterial culture media from *Corynebacterium murisepticus* or *microbacterium* species (Ishiyama, 1975). The biosynthesis of a molecule by a cell in which it has been found is important in proving its status as a normal metabolite, because otherwise, one might conclude that caffeine, nicotine or aspirin are normal human metabolites. These compounds can be isolated from many individuals, are metabolized by the body and have many pharmacological effects which might easily be mistaken for physiological functions.

A number of different phosphodiesterases (PDE's) have been described for cyclic CMP. One, which has been purified by Conrad and Bloch (1980), is of relatively high molecular weight and low K_m and is apparently specific for cyclic CMP only. Another PDE, which has been purified by Helfman et al., (1980), hydrolizes both cyclic AMP and cyclic CMP at different sites and has a molecular weight of only 33,000. Interestingly enough, the cyclic CMP PDE's are not inhibited by the methyl xanthines as are the PDE's of the purine cyclic nucleotides.

Cech and Ignarro (1977 and 1978) using alpha^{32}P labeled CTP as substrate with either Ma^{++} or Fe^{++} as cofactors at neutral pH, reported the biosynthesis of cyclic CMP in both mouse and rat liver homogenates, both normal and regenerating, as well as in other rodent tissues. The product was reported as having been characterized with alumina column chromatography, on Dowex-1-formate, PEI cellulose, and recrystallization to constant specific activity in two solvents. However, Krishna (1979) showed that the presumed ^{32}P cyclic CMP had a different Rf from the ^{3}H cyclic CMP marking pool. We investigated a similar system and found a large number of radioimmunoreactive compounds among the products of the reaction. Thus, this area is in complete disarray at the present time. Recently Wikberg et al., (1981) has demonstrated the problem quite clearly (Fig. 4 and 5).

Figure 4 shows work carried out by Wikberg, who has developed a radioimmunoassay quite similar to the others, but which uses ^{3}H cyclic CMP as the labelled compound to be displaced from the antibody rather than ^{125}L methyl tyrosine derivatives used in the other systems. This figure compares to different chromatographs carried out on identical 0.9 × 15 cm AG1-X-8-formate coumns eluted with 0.2 N formic acid. One column, the solid line, was loaded with perchloric acid soluble fraction from 3-5 grams of rat liver, and an identically loaded column was further charged with 10 pMoles of ^{3}H cyclic CMP. The solid line represents radioimmunoreactivity, and the dotted line, radioactivity. It is evident that these peaks do not coincide. Figure 5 is similar, but the tandem column was loaded with 10 pMoles of unlabeled cyclic CMP. In this figure, the dotted line represents radioimmunoreactivity on the tandem column.

The treatment of CRIRM with pronase, a proteolytic enzyme, increases the radioimmunoreactive cyclic CMP material by a factor of 4 but does not change its Rf. It should be evident that a radioimmunoassay which does not distinguish between the compound it was designed to quantitate and a different uncharacterized material is of doubtful value.

CRIRM has been noted by others but has been assumed to be a peptide which binds cyclic CMP and which competes with the antibody for the nucleotide. On the other hand, the material may be a peptide which is an artifact of extraction with perchloric acid and which has a sequence of amino acids identical to some portion of the carrier protein molecule, originally used to make the antibody. This is not likely since a variety of proteins have been used as carriers among the radioimmunoassays in use.

Figure 6 (Murphy and Stone, 1980) was produced by measuring the changes in cyclic CMP in regenerating liver after partial hepatectomy. The animals were accompanied by suitable control groups. The perchlorate soluble supernatants were chromatographed upon 3 × 1 cm Dowex-1-formate columns with 0.1 formic acid. The samples in the peak tubes were further characterized by TLC in which the CRIRM material was co-chromatographed with ^{3}H cyclic CMP and unlabeled cyclic CMP.

It would be most interesting to ascertain if radioimmunoassayable reactive material similar to that isolated in cyclic radioimmunoassay would be found for cyclic AMP and cyclic GMP in Wikberg type systems. The close approximation of the Rf of Wikberg's CRIRM peak with cyclic CMP itself is a technical problem which must be solved before this area can progress.

It is the opinion of Bloch, and also of the present authors, that cyclic CMP is a rather common cyclic nucleotide, but it is usually bound to some cellular constituents(s), and it may appear in free form for only relatively short periods during some physiological process in a manner analogous to norepinephrine or acetycholine.

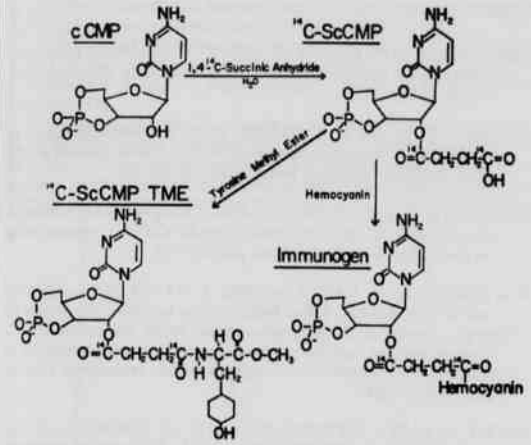

Figure 1. Structures of cyclic CMP derivatives synthesized.

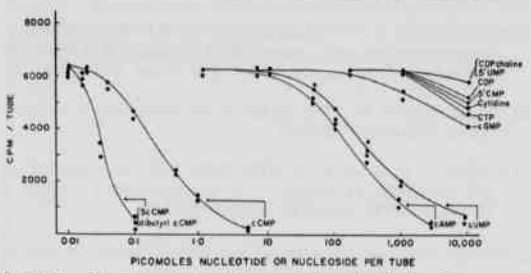

Figure 3. Cross-reactivity of the succinyl cyclic CMP antiserum.

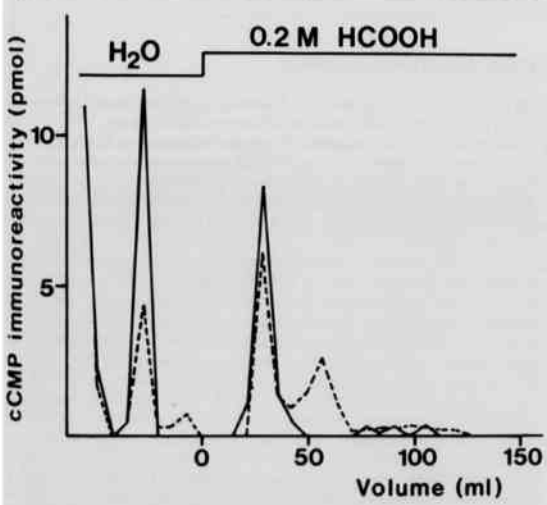

Figure 5. Chromatography of cold perchloric acid extracts from rat liver with unlabelled cyclic CMP added to tandem column. (From Wikberg et al., 1981).

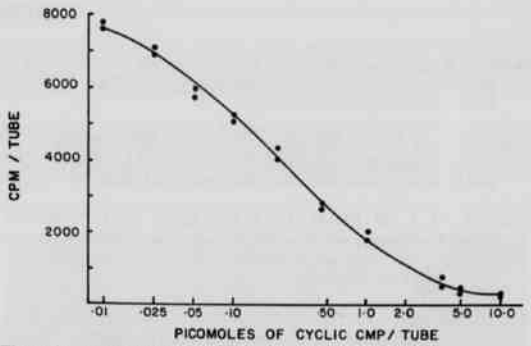

Figure 2. Standard immunoassay curve for cyclic CMP.

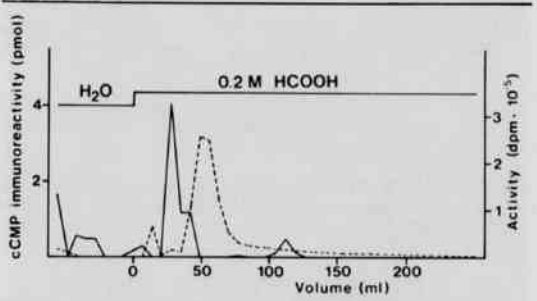

Figure 4. Chromatography of cold perchloric acid extracts of rat liver on large with ³H cyclic CMP marking pool added. AG 1-X8 columns. (From Wikberg et al., 1981).

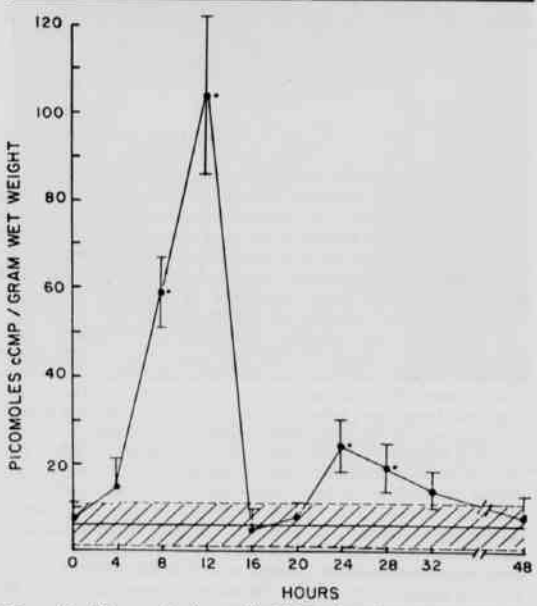

Figure 6. Changes in the cyclic CMP of rat liver following 70% hepatectomy. (From Murphy and Stone, 1980).

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ANOMALIES OF BOBCAT SKULLS (*FELIS RUFUS*) IN ARKANSAS

Examination of 275 bobcat skulls (*Felis rufus*) from Arkansas, preserved in the Collection of Recent Mammals, Arkansas State University Museum of Zoology (ASUMZ), revealed five anomalous forms which ranged from dental irregularity to supernumerary cranial bones.

Sutural anomalies were found in several skulls. The normal junction of the coronal (C) and sagittal (S) sutures is illustrated in Figure 1, # 6926. This bregmatic junction forms after fontanelle ossification of the frontal and parietal bones. In the fetal skull, cartilagenous "soft spots" or fontanelles exist at the future junctional site, and if ossification among the bones is uneven, waved or otherwise malformed sutures may result. Two of the more pronounced sutural anomalies found in Arkansas bobcats are illustrated in Figure 1, #'s 7706 and 6765. Bregmatic bone formation can also cause abnormal junctions if ankylosis obliterates one or more sutures (Pratt, 1942; Manville, 1959). We did not attempt to distinguish between anomalies caused by these factors.

Bregmatic bones (those formed at the anterior fontanelle) occur commonly in the beaver (*Castor*) and porcupine (*Erethizon*) (Schultz, 1923) and result from one or more ossification centers developing in the anterior fontanelle, thereby forming additional bones as the parietals and frontals complete ossification around them. Occurrences of bregmatic bones in bobcats are discussed in the literature (Pratt, 1942; Manville, 1959; Mahan, 1980). Hall and Kelson (1959) (probably unknowingly) depicted a bregmatic bone in their illustration of a bobcat skull. Bregmatic fontanelle bones were found in 41 of 275 (14.9%) Arkansas bobcat skulls examined, and varied in size, shape, and number. Representatives of variations seen in Arkansas skulls are illustrated in Figure 2. The nature of these bones in Arkansas bobcats is similar to reports from other areas: 14.7% in Nebraska (Mahan, 1980); 16.8% in Oregon, 14.6% in Nevada, 15.5% nationally (as represented in the U. S. National Museum) (Manville, 1959). Manville also pointed out deviations from this apparent trend: 37.5% of 32 specimens from West Virginia, 44.0% of nine from Mississippi and 7.0% of 158 from Texas. Pratt (1942) found anomalous bones in 17.5% of his museum study material, and Progulske (1952) found 15 of 72 (20.8%) skulls from Virginia and North Carolina to have anomalous bones. Usually, only a single extra bone occurs; however, in the Arkansas material examined, one skull (Fig. 2, # 7471) exhibited two additional bones (0.4% of sample). Similarly, Mahan (1980) found only one such pair of bones (0.9%) in Nebraska and Pratt (1942) reported two (0.12% of his sample). Furthermore, Pratt reported only one incidence involving three anomalous bones in a sample of 2154 skulls. ASUMZ 7734 (Fig. 2) illustrates an Arkansas specimen exhibiting this trinity of extra bones (0.4% of sample), representing the second documented record. No correlation was found between sex or geographic location and presence of anomalous bones in Arkansas bobcats.

Wormian bones are those which are sutural in origin, as contrasted with bregmatic bones which are fontanellic in origin. It is sometimes

impossible to distinguish between these, as they are often closely associated (Schultz, 1923). One Arkansas bobcat skull demonstrated a distinguishable wormian bone, illustrated in Figure 2, # 6784.

Two dental anomalies were discovered, neither of which have been reported previously. The only previous dental anomaly reported involved the occurrence of double incisors (Rollings, 1945; Pollack, 1949). One skull from Arkansas was found to have a misdirected right upper first premolar. Instead of replacing the lacteal tooth which had been lost, the permanent premolar appeared on the lingual side of the second premolar (Fig. 3).

An additional dental anomaly found during this study involved misalignment of the lower incisors. Normally, these incisors lie in a straight line (Fig. 4A). Due to crowding or other factors, incisors in some jaws occurred out of line, resulting in a wavy appearance of the incisor row (Fig. 4B). The most extreme example of this anomaly consisted of the outer incisors (those adjoining the canines) having been forced completely anterior to the other incisors, which maintained a straight line formation (Fig. 4C).

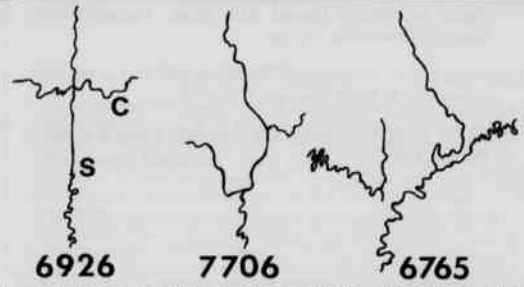

Figure 1. Representative sutural anomalies found in Arkansas bobcat skulls. Normal sutural junction indicated in ASUMZ 6926 (S-sagittal suture, C-coronal suture).

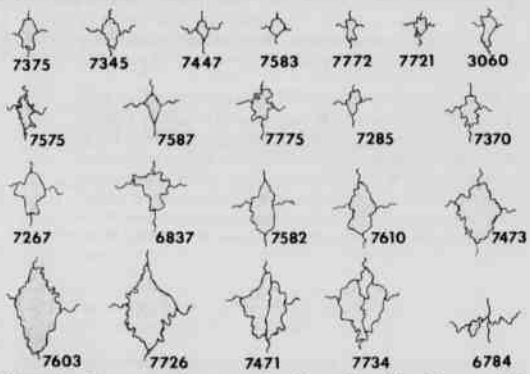

Figure 2. Representative anomalous bones found in Arkansas bobcat skulls (numbers indicate ASUMZ catalog references).

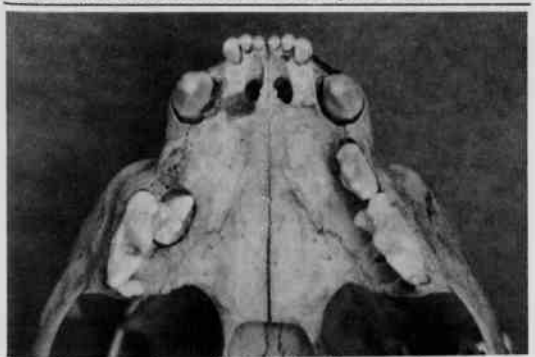

Figure 3. Anomalous position of the right upper first premolar. Note the left jaw maintained the normal arrangement.

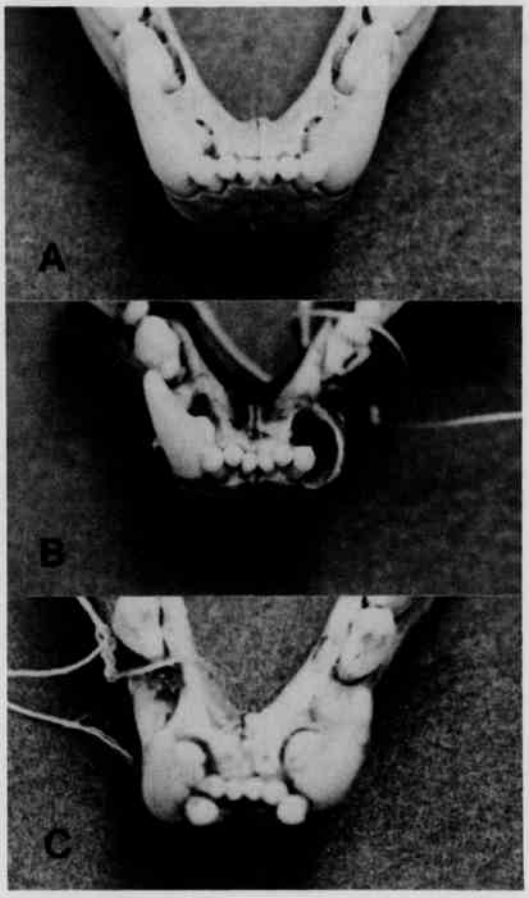

Figure 4. Misaligned incisors of Arkansas bobcats. A - normal linear arrangement. B - misalignment producing wavy appearance. C - misalignment forcing third incisor completely anterior to other incisors.

The authors wish to thank Mr. Lew Johnston of the Arkansas Game and Fish Commission for providing many of the skulls examined.

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ERRATUM

The sixth paragraph of the paper, *"Immune responses of rats to antigens of Moloney leukemia virus,"* by Frances B. Soderberg, Susan G. Tai and Joe M. Jones, *Proc. Ark. Acad. Sci.*, 34:133-34, has an incorrect sentence. The corrected paragraph, in its entirety, is published below:

Table 2 shows that when immunized with oncogenic virus (MuLV) or with tumor cells (MST), BN rats exhibit high antibody responses and LEW low responses. LEW-1n congenics with RT1n of BN bred on a LEW background exhibited responses similar to LEW. TO rats, which differ genetically from all of the other three strains, exhibited responses similar to BN to p30 and responses lower than BN to gp70. This shows that higher responders to p30 are not automatically higher responders to other viral polypeptides. Table 3 shows that the phenomenon observed with LEW-1n was not confined to the p30 antigen. Although AS2 rats exhibited significant responses to p15 of MuLZ, LEW-1f congenics carrying the RT1f of AS2 on a LEW background were low or non-responders to p15. LEW-1f were also low responders to gp70 when immunized with MuLV (% precipitation 3.8 $\pm$ 2.6), and LEW rats were low responders to p15, p30 and gp70 in all tests when immunized with MuLV.

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FLEMING, T. H. 1969. Population ecology of three species of Neotropical rodents. Unpublished Ph.D. dissertation, Univ. Michigan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger *(Taxidea taxus)*. Pp. 27-45, *In* Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

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